Chapter 2
Higher Education in Science and Engineering

Highlights

Demographics

♦ **The size of the college-age population has decreased in all major industrialized countries although within different time frames.** The U.S. college-age population decreased from 22 million in 1980 to 17.5 million in 1997, a reduction of 23 percent. Europe's college-age population has begun a steeper decline, from 30 million in 1985 to 22 million in 2005, a reduction of 27 percent. Japan's college-age population of 10 million, which began to decline in 1995, is projected to reach a low of 7 million in 2015, representing a loss of 30 percent.

♦ **In the United States, the nearly 20-year population decline in the size of the college-age cohort reversed in 1997 and is projected to increase from 17.5 million to 21.2 million by 2010, with strong growth among minority groups.** This increase in the college-age population by more than 13 percent in the first decade of the 21st century signals another wave of expansion in the nation's higher education system and growth in science and engineering (S&E) degrees at all levels.

♦ **Demographic trends show an increase in the minority population in the United States.** The traditional college-age population of white students will expand slowly until 2010 and then decline, whereas the traditional college-age population of racial and ethnic minorities will continue to rise. These trends offer a challenge to the United States to educate students who have been traditionally underrepresented in S&E.

Characteristics of Higher Education by Type of Institution

♦ **Overall enrollment in the nation's institutions of higher education increased from 7 million in 1967 to 15 million in 1992 and then continued essentially unchanged through 1997.** Enrollment in higher education is expected to increase in the first decade of the 21st century because of a predicted 13 percent increase in the population of the college-age cohort during this period.

♦ **Research universities enroll only 19 percent of the students in higher education, but they play the largest role in S&E degree production.** They produce most of the engineering degrees and a large proportion of natural and social science degrees at both the graduate and undergraduate levels. In 1998, the nation's 127 research universities awarded more than 42 percent of all S&E bachelor's degrees and 52 percent of all S&E master's degrees.

♦ **By 1997, enrollment in community colleges was 38 percent of the total enrollment in higher education.** Community colleges serve a diverse population of students and have a broad set of missions. They confer associate degrees, serve as a bridge for students to attend four-year colleges, and expand the supply of information technology workers through certificate programs. They offer a wide array of remedial courses and services and enroll millions of students in noncredit and workforce training classes.

♦ **Traditional institutions of higher education are augmented by industrial learning centers, distance education, and certificate programs.** Substantial education within industry is at the level of higher education and oriented toward engineering, design, and business management. Interest in taking S&E courses and entire programs via distance education is growing. In 1997, more than 50,000 different on-line courses were offered by postsecondary institutions, and 91 percent of those were college-level credit courses.

Undergraduate S&E Students and Degrees in the United States

♦ **A key challenge for undergraduate education is preparing K–12 teachers in science and mathematics.** In the upcoming decade, the nation's school districts will need to hire 2.2 million new teachers, including 240,000 middle and high school mathematics and science teachers. Of the total, 70 percent will be new to the profession because of older teachers retiring and the increase in student population.

♦ **The percentage of high school graduates enrolling in college is increasing for some racial groups.** By 1999, approximately 45 percent of white and 39 percent of black high school graduates were enrolled in college, up from approximately 31 and 29 percent, respectively, in 1979. In contrast, during this period, enrollment rates in higher education for Hispanic high school graduates increased only slightly, from 30 to 32 percent.

♦ **In the past two decades, the proportion of white students in the nation's undergraduate student enrollment decreased, falling from 80 percent in 1978 to 70 percent in 1997.** The proportion of underrepresented minorities increased the most, from 15.7 to 21.7 percent; Asians/Pacific Islanders increased from 2.0 to 5.8 percent, and foreign students remained at approximately 2 percent of undergraduate enrollment.

♦ **Women outnumber men in undergraduate enrollment for every race and ethnic group.** White women constitute 55 percent of white undergraduate students, and black women constitute 62 percent of black undergraduate enrollment.

♦ **The long-term trend has been for fewer students to enroll in engineering.** Undergraduate engineering enrollment declined by more than 20 percent, from 441,000 students in 1983 (the peak year) to 361,000 students in 1999. Graduate engineering enrollment peaked in 1993 and continues to decline.

- **Approximately 25–30 percent of students entering college in the United States intend to major in S&E fields, but a considerable gap exists between freshman intentions and successful completion of S&E degrees.** Fewer than 50 percent of those who intend to major in S&E fields complete an S&E degree within five years. Underrepresented minorities drop out of S&E programs at a higher rate than other groups.
- **For the past several decades, about one-third of bachelor's degrees have been awarded in S&E fields, but from 1986 to 1998, the percentage of engineering degrees decreased from 8 to 5 percent of total undergraduate degrees.** Since 1986, the percentage of bachelor's degrees earned by undergraduates also has declined slightly in physical sciences, mathematics, and computer sciences. In contrast, since 1986, students have earned a higher percentage of bachelor's degrees in social and behavioral sciences and in biological sciences.
- **The ratio of natural science and engineering (NS&E) degrees to the population of 24-year-olds in the United States has been between 4 and 5 per 100 for the past several decades and reached 6 per 100 in 1998.** Several Asian and European countries, however, have higher participation rates, and the U.S. gap in educational attainment between whites and racial/ethnic minorities continues to be wide; the rate of earning NS&E degrees for racial/ethnic minorities is still less than half the rate of the total population.

Graduate S&E Students and Degrees in the United States

- **Long-term trends show that the proportion of women enrolled in all graduate S&E fields is increasing.** By 1999, women constituted 59 percent of the graduate enrollment in social and behavioral sciences, 43 percent of the graduate enrollment in natural sciences, and 20 percent of the graduate enrollment in engineering. Women in underrepresented minority groups have a higher proportion of graduate enrollment than women in other groups; one-third of black graduate students in engineering and more than one-half of the black graduate students in natural sciences are women.
- **Long-term trends show that the enrollment of foreign graduate students in S&E fields in the United States is increasing.** This increase, coupled with a declining number of American white (majority) students, resulted in an approximately equal number of American white and foreign students in U.S. graduate programs in mathematics, computer sciences, and engineering in 1999.
- **After a steady upward trend during the past two decades, the overall number of earned doctoral degrees in S&E fields declined in 1999.** Trends differ by field. Degrees in biological sciences followed the overall pattern and declined for the first time in 1999. Strong increases in the number of degrees earned in engineering peaked in 1996 and were followed by three years of decline. This decrease in the number of engineering degrees earned is accounted for mainly by the decrease in the number of degrees earned by foreign students from 1996 to 1999.
- **At the doctoral level, the proportion of S&E degrees earned by women has risen considerably in the past three decades, reaching a record 43 percent in 1999.** However, dramatic differences by field exist. In 1999, women earned 42 percent of doctoral degrees in the social sciences; 41 percent of those in biological and agricultural sciences; 23 percent of those in physical sciences; 18 percent of those in computer sciences; and 15 percent of those in engineering.
- **Each year from 1986 to 1996, the number of foreign students earning S&E doctoral degrees from universities in the United States increased; it declined every year thereafter.** During the period 1986–99, foreign students earned 120,000 doctoral degrees in S&E fields. China was the top country of origin of these foreign students; almost 24,000 Chinese earned S&E doctoral degrees at universities in the United States during this period.
- **The National Institutes of Health (NIH) and the National Science Foundation support most of the S&E graduate students whose primary support comes from the Federal Government, 17,000 and 14,000 students, respectively.** The proportion of students supported primarily by NIH increased from less than 22 percent in 1980 to 29 percent in 1999; those supported primarily by NSF increased from less than 18 percent in 1980 to 21 percent in 1999. In contrast, the Department of Defense provided primary support for a declining proportion of students funded primarily by Federal sources, 17 percent in 1988 and 12 percent in 1999.
- **By 1999, more than 72 percent of foreign students who earned S&E doctoral degrees at universities in the United States reported that they planned to stay in the United States after graduation, and 50 percent accepted firm offers to do so.** These percentages in the late 1990s represent significant increases. Historically, approximately 50 percent of foreign doctoral recipients planned to stay in the United States after graduation, and a smaller proportion had firm offers to do so.
- **Although the number of foreign doctoral recipients planning to stay in the United States increased in the 1990s, opportunities are expanding for returning to their home countries or for collaborative research and networking with home-country scientists.** Taiwan and South Korea have been the most able to absorb Ph.D.-holding scientists and engineers trained abroad. Some of this recruitment occurs after a distinguished science career abroad.

Increasing Global Capacity in S&E

- **In 1999, more than 2.6 million students worldwide earned a bachelor's degree in science or engineering.** More than 1.1 million of the 2.6 million S&E degrees were earned by Asian students at Asian universities. Students across Europe (including Eastern Europe and Russia) earned almost 800,000 first university degrees in S&E fields. Students in North America earned more than 600,000 S&E bachelor's degrees.

- **Trend data for bachelor's degrees show that the number of degrees earned in the United States remained stable or declined in the 1990s in all fields except psychology and biology.** In contrast, trend data available for selected Asian countries show strong growth in degree production in all S&E fields. At the bachelor's level, institutions of higher education in Asian countries produce approximately six times as many engineering degrees as do institutions in the United States.

- **Although the United States has traditionally been a world leader in providing broad access to higher education, other countries have expanded their higher education systems, and the United States is now 1 of 10 countries providing a college education to approximately one-third or more of their college-age population.** The ratio of natural science and engineering (NS&E) degrees to the college-age population is higher than in the United States in more than 16 other countries.

- **Among some Asian countries, women earn first university degrees at a rate similar to or higher than the corresponding rate in many European countries.** However, only in South Korea do women have high participation rates in NS&E degree programs. In 1998, the ratio of women-earned degrees in these fields to the female population of 24-year-olds was 4.6 per 100, higher than the participation rate of women in other Asian countries, Germany, or the United States.

- **The group of traditional host countries for many foreign students (United States, France, and United Kingdom) is expanding to include Japan, Germany, and Australia, and the proportion of foreign graduate students is increasing in these countries.** Foreign S&E graduate student enrollment in the United Kingdom increased from 28.9 percent in 1995 to 31.5 percent in 1999. Percentages differ by field; foreign student graduate enrollment in U.K. universities reached 37.6 percent in engineering and 40 percent in social and behavioral sciences.

- **Developing Asian countries, starting from a very low base in the 1970s and 1980s, have increased their S&E doctoral production by several orders of magnitude. China now produces the most S&E doctoral degrees in Asia and ranks fifth in the world.** Within Europe, France, Germany, and the United Kingdom have almost doubled their S&E doctoral degree production in the past two decades, with slight declines in 1998.

- **Because of the growing capacity of some developing Asian countries and economies (China, South Korea, and Taiwan) to provide advanced S&E education, the proportion of doctoral degrees earned by their citizens in the United States has decreased.** In the past five years, Chinese and South Korean students earned more S&E doctoral degrees in their respective countries than in the United States; in 1999, Taiwanese students for the first time earned more S&E doctoral degrees at Taiwanese universities than at U.S. universities.

- **In 1999, Europe produced far more S&E doctoral degrees (54,000) than the United States (26,000) or Asia (21,000).** Considering broad fields of science, most of the doctorates earned in natural sciences, social sciences, and engineering are earned at European universities. The United States awards more doctoral degrees in natural and social sciences than Asian countries.

- **Like the United States, the United Kingdom and France have a large percentage of foreign students in their S&E doctoral programs.** In 1999, foreign students earned 44 percent of the doctoral engineering degrees awarded by U.K. universities, 30 percent of those awarded by French universities, and 49 percent of those awarded by universities in the United States. In that same year, foreign students earned more than 31 percent of the doctoral degrees awarded in computer sciences in France, 38 percent of those awarded in the United Kingdom, and 47 percent of those awarded in the United States.

Introduction

Chapter Overview

Among the diverse goals of the U.S. higher education system, two are particularly important to the science and engineering (S&E) fields. In addition to enhancing the broad intellectual capabilities of students, higher education prepares students to meet the needs of the 21st-century workforce. With the decline in the U.S. college-age population from 1980 to 1997 and subsequent falloff in degrees in many S&E fields, U.S. universities began to rely on foreign students to fill graduate S&E programs, particularly in the physical sciences, engineering, and computer sciences. As national demographic trends shift and minority populations become a larger proportion of the college-age cohort, U.S. higher education institutions are being challenged to attract and retain minority students who have been underrepresented in the S&E fields.

The U.S. higher education system also is responding to a growing movement across countries to enlist universities more explicitly into national innovation systems. For several decades, many countries have strengthened their higher education in S&E fields as a strategy for development, based on an assertion that advanced S&E knowledge would bolster their economies. In the 1990s, this assertion gained widespread acceptance, and most industrial and developing countries began improving their higher education systems, particularly in natural sciences, mathematics, engineering, and technology, as a necessary part of preparing for a "knowledge economy." Indicators of this international movement toward science and technology (S&T) education for development are:

- increased growth rate in the number of degrees in S&E fields among industrialized countries and developing nations,
- increased flow of foreign graduate students to study S&E fields in advanced countries,
- increased recruiting of foreign students by advanced countries that have a declining college-age population, and
- expanded options for mobility by foreign S&E doctorate-holders in terms of remaining abroad, returning home, or circulating between home and abroad during their careers.

As higher education in the United States contributes to these international trends[1] and also attempts to better prepare U.S. students for S&E careers, various changes are taking place:

- The infrastructure for S&E education is expanding beyond the traditional institutions of higher education to an array of flexible and interconnected learning modes.
- The scope of concern in S&E education is expanding to include both the focused education of S&E majors and the goal that all college students acquire scientific and technical literacy.
- The delivery of S&E instruction is changing through new teaching methods and innovative uses of information technology (IT).
- Student strategies for acquiring knowledge are changing to incorporate both traditional and new modes of higher education delivery.
- The growing proportion of underrepresented minority groups in the student body is forcing a movement to raise their participation in S&E.

Chapter Organization

The chapter begins with U.S. higher education and traditional education indicators of enrollment and degrees in S&E fields in different types of institutions. Overall demographic trends are discussed, including trends among U.S. subpopulations that are increasing minorities among the college-age cohort. The chapter describes traditional and new mechanisms for delivering higher education in S&E fields and, when possible, quantifies the activity outside formal academic institutions. For each level of higher education, enrollment and degrees are analyzed by sex, race/ethnicity, and citizenship. The chapter provides indicators of U.S. undergraduate students' initial interest in studying S&E, the persistent need during the past 20 years for remedial coursework, and the recently declining number of degrees in most S&E fields at all levels within traditional institutions of higher education. Efforts to reform undergraduate education aimed at raising the quantity and quality of U.S. students in S&E fields and at meeting all student needs for quantitative and scientific understanding are discussed. The chapter highlights trends in U.S. graduate S&E education and discusses reforms that attempt to broaden education and career options. Changing patterns of mobility and reverse flow of foreign students also are discussed.

The final section describes global trends that place U.S. higher education in an international context. For example, cross-regional trends in S&E degrees conferred show the acceleration of such degrees at the bachelor's and doctoral levels. The stronger participation rates in S&E among college-age cohorts in Europe and Asia are contrasted with participation rates in the United States. The flow of foreign students to the United States is compared with the increasing flow to the United Kingdom and Japan. The reverse flows of foreign doctorate-holders by field and country of origin are compared across the United States, United Kingdom, and France.

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[1]U.S. institutions and S&E faculty are active in international distance education in developing countries, advise on establishing centers of excellence, accept students from abroad, and establish international collaborative research with their former students. (See, for example, Michael Arnon, 2001, "U. of Maryland Will Help Uzbekistan Create a Virtual University," *The Chronicle of Higher Education*, August 29; Eugene S. Takle, "Global Climate Change Course," Iowa State University, International Institute of Theoretical and Applied Physics, available at <http://www.iitap.iastate.edu/gccourse>: and E.S. Takle, M.R. Taber, and D. Fils, "An Interdisciplinary Internet Course on Global Change for Present and Future Decision-makers," Keynote presentation at the International Symposium on the Learning Society and the Water Environment, Paris, June 2–4, 1999.)

U.S. Higher Education in S&E

A key challenge for the higher education system in the United States is to remain a leader "in generating scientific and technological breakthroughs and in preparing workers to meet the evolving demands for skilled labor" (Greenspan 2000). The needs of the workplace are changing in today's information- and service-oriented economy; all workers require increased competency in mathematics and critical thinking and, at minimum, an understanding of basic science and technology concepts (Romer 2000). Despite the rising number of college-age adults (see "Demographics and Higher Education"), the National Science and Technology Council (NSTC 2000) has expressed concern about the nation's ability to meet its technical workforce needs and to maintain its international position in S&E. This section explains demographic trends that may affect higher education in the United States as well as institutional resources, both traditional and emerging, that are being mobilized to meet this challenge. The section includes data on the growing enrollment in S&E degree programs and the production of S&E degrees by type of institution. The growing importance of community colleges in lifelong learning and their role in teaching IT are also described.

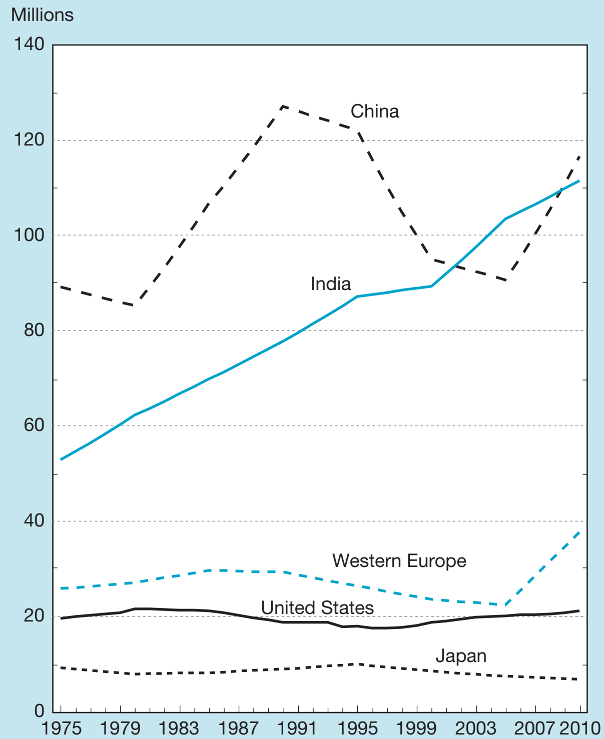
Demographics and Higher Education

Past Trends

The size of the college-age cohort has decreased in all major industrialized countries, although within somewhat different time frames. The U.S. college-age population decreased from 22 million in 1980 to 17 million in 1997, a reduction of 23 percent. Europe's college-age population has begun an even steeper decline, from 30 million in 1985 to a projected 22 million in 2005, a reduction of 27 percent. Japan's college-age population of 10 million, which began to decline in 1995, is projected to reach a low of 7 million in 2010, representing a loss of 30 percent. (See appendix table 2-1.)

Based on these trends, the major industrialized countries have recruited foreign students to help fill their graduate S&E departments. See "International Comparisons of Foreign Student Enrollment in S&E Programs" at the end of this chapter. Most of these foreign students have been drawn from developing countries with far larger populations of potential college students. For example, China and India are major countries of origin for foreign graduate students in the United States, each with approximately 90 million in their college-age cohort. (See figure 2-1.)

Figure 2-1.
Trends in population of 20- to 24-year-olds in selected countries and regions: 1975–2010



See appendix table 2-1. *Science & Engineering Indicators – 2002*

Current Trends

In the United States, the almost 20-year decline of the college-age cohort reversed in 1997 and is projected to increase from 17.5 million to 21.2 million by 2010, with strong growth among minority groups. (See appendix tables 2-1 and 2-2.) This projected increase in the college-age population by more than 13 percent in the first decade of the 21st century, coupled with the high percentage of the college-age population electing to attend college, signals another wave of expansion in enrollment in the U.S. higher education system and growth in S&E degrees at all levels.

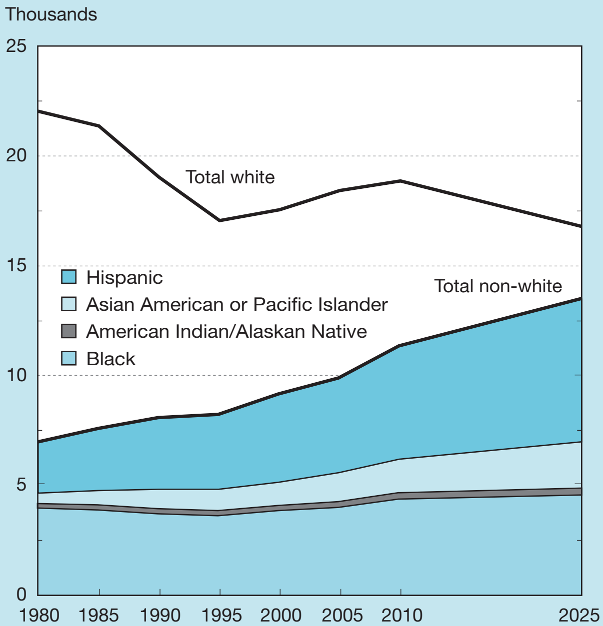
Demographic trends show an increase in the minority group population in the United States. (See figure 2-2.) The white college-age population will expand slowly until 2010 and then decline, whereas the college-age population of racial and ethnic minorities will continue to rise. These trends offer a challenge to the United States and an opportunity to educate students who have been traditionally underrepresented in S&E fields (e.g., women, blacks, Hispanics, and American Indians/Alaskan Natives).

Characteristics of U.S. Higher Education Institutions

The defining characteristics of the U.S. higher education system include broad access to an array of institution types and sizes with public and private funding and flexible attendance patterns. New ways of acquiring advanced training and skills outside these institutions are augmenting access (see "New Modes of Delivery"). As other countries broaden their access to higher education, a wider array of institution types and attendance patterns is also evolving internationally.

U.S. higher education includes nearly 3,400 degree-granting colleges and universities serving 14.5 million students, nearly 80 percent of whom attend public institutions. In 1997, approxi-

Figure 2-2.
U.S. population of 18- to 24-year-olds, by race/ethnicity: 1980–2025



See appendix table 2-2. *Science & Engineering Indicators – 2002*

mately 5.5 million of these students attended two-year institutions. Institutions of higher education at all levels awarded 2.2 million degrees in 1998, almost one-quarter of which were in S&E fields. (See figure 2-3.) Less than 8 percent of all students are enrolled in private liberal arts I and II institutions, and 19 percent attend research universities, as defined by the Carnegie Classification. (See appendix table 2-3 and sidebar, "Carnegie Classification of Academic Institutions.") The demographic and college attendance patterns of the student population are changing. More than 50 percent of all undergraduates are age 22 or older, almost 25 percent are age 30 or older, and 40 percent of all students are attending college part time (Edgerton 1997).

Traditional Institutions of Higher Education

The Carnegie Foundation for the Advancement of Teaching (1994) has clustered institutions with similar programs and purposes to better describe the diverse set of traditional institutions serving various needs. The 2000 Carnegie Classification is under review, and new categories are being defined that combine doctoral and research universities. The changes omit references to the amount of research support different institutions have received (McCormick 2000). For the 1997/98 academic year enrollment and degree data used in this chapter, the former 1994 Carnegie Classification applies.

Enrollment in U.S. Higher Education by Type of Institution

Overall enrollment in U.S. institutions of higher education increased from 7 million in 1967 to 15 million in 1992 and then continued essentially unchanged through 1997. (See figure 2-4.) The expansion period represented an average annual growth rate of 3 percent, but growth rates differed greatly by type of institution. For example, two-year colleges grew at twice this rate and accounted for the largest share of the growth, from 1.5 million students in 1967 to 5.5 million in 1997 (including full- and part-time students).[2] By 1997, enrollment in two-year colleges was 38 percent of total higher education enrollment. In contrast, total student enrollment in research universities I grew more modestly, from 1.5 million students in 1967 to 2.1 million in 1992, with fluctuations around 2.1 million enrollments until 1997. Research universities enroll only 19 percent of the students in higher education, but they play the largest role in S&E degree production. (See figure 2-3 and appendix table 2-5.) Enrollment in higher education is expected to increase in the first decade of the 21st century because of a 13 percent increase in the college-age cohort during this period. (See appendix table 2-1.)

S&E Degree Production at All Levels of Higher Education by Type of Institution

Research-intensive universities produce most of the engineering degrees and a large proportion of natural and social science degrees at both the graduate and undergraduate levels. (See figures 2-5 and 2-6.) In 1998, the nation's 127 research universities awarded more than 42 percent of all S&E bachelor's degrees and 52 percent of all S&E master's degrees. In addition, comprehensive and liberal arts I institutions awarded significant numbers of bachelor's and master's degrees in S&E. Associate degrees awarded by community colleges accounted for only a small percentage of total S&E degrees awarded but serve other important functions.

S&E Faculty by Type of Institution

More than 1.1 million faculty teach in the approximately 3,400 degree-granting institutions of higher education. A large proportion (approximately two-fifths) of all faculty work part time. Some institutions rely on part-time faculty to a greater degree than others; almost two-thirds (65 percent) of faculty at public two-year institutions hold part-time appointments, and approximately one-fifth of faculty at public research institutions work part time. (See text table 2-1.)

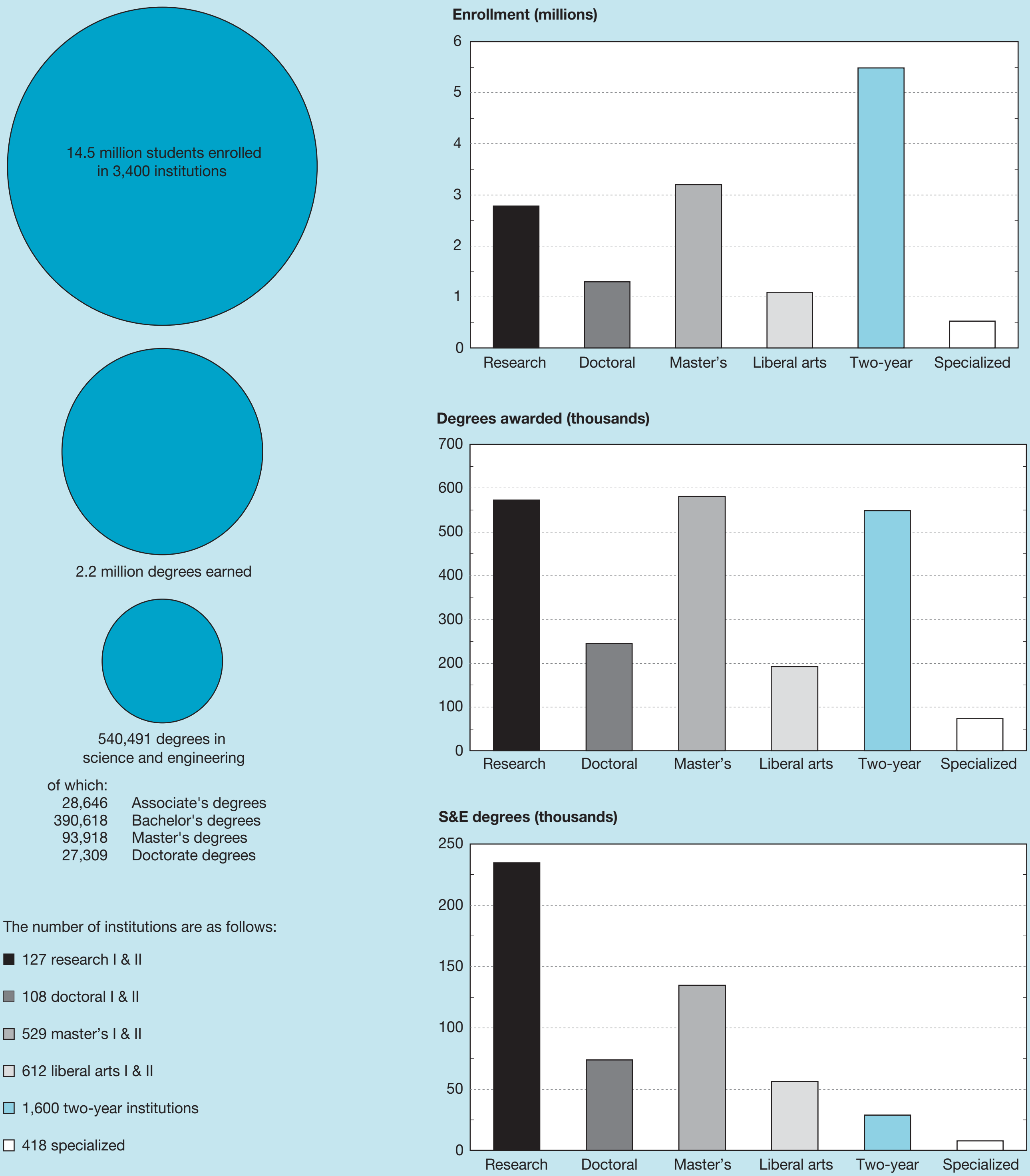
Underrepresented minority faculty in S&E fields are more concentrated at the associate level or in part-time positions at four-year institutions. They constituted only 6 percent of the full-time faculty who teach engineering and computer sciences at four-year institutions but 10 percent of the full-time faculty teaching subjects in these fields at community colleges. (See text table 2-2 and appendix table 2-6.)

Community Colleges

Community colleges serve a diverse student population and have a broad set of missions: they confer certificates and

[2]An additional 5 million students are estimated to be enrolled in noncredit courses in community colleges and are not counted in the overall enrollment in higher education.

Figure 2-3.
Profile of U.S. higher education by students, institutions, and degrees at all levels: 1998



NOTES: The 355 institutions classified as "other" are not included. Enrollment data are for fall 1997; degree data are for 1998.

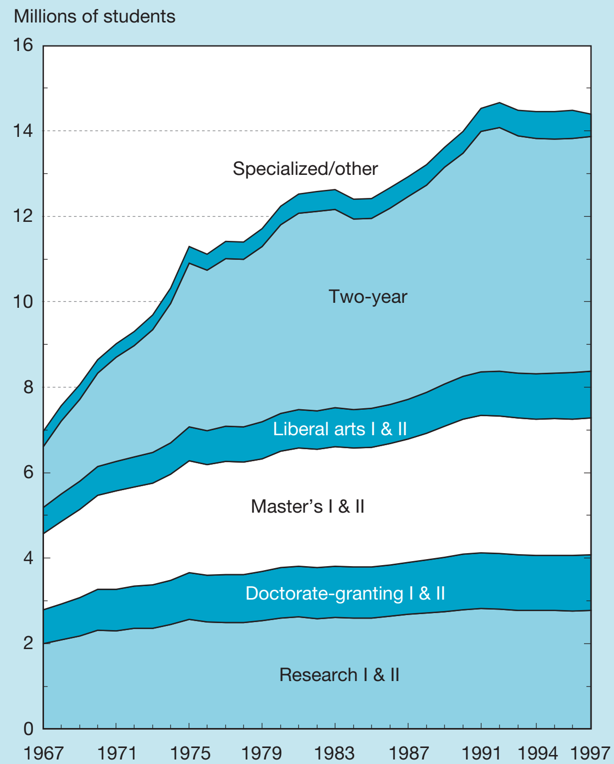
See appendix tables 2-3, 2-4, and 2-5. *Science & Engineering Indicators – 2002*

Carnegie Classification of Academic Institutions

- **Research universities I** (89)* offer a full range of baccalaureate programs, are committed to graduate education through the doctorate level, award 50 or more doctoral degrees, and receive $40 million or more in Federal research support annually.
- **Research universities II** (38) are the same as research universities I, except that they receive between $15.5 million and $40 million in Federal research support annually.
- **Doctorate-granting I** (50) institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctoral degree, and award 40 or more doctoral degrees annually in at least five academic disciplines.
- **Doctorate-granting II** (58) institutions award 20 or more doctoral degrees annually in at least one discipline or 10 or more doctoral degrees in three disciplines.
- **Master's (comprehensive) universities and colleges I** (438) offer baccalaureate programs and, with few exceptions, graduate education through master's degrees. More than 50 percent of their bachelor's degrees are awarded in two or more occupational or professional disciplines, such as engineering and business administration. All of the institutions in this group enroll at least 2,500 students.
- **Master's (comprehensive) universities and colleges II** (91) enroll between 1,500 and 2,500 students.
- **Baccalaureate (liberal arts) colleges I** (162) are highly selective, primarily undergraduate colleges that award more than 40 percent of their bachelor's degrees in the liberal arts and science fields.
- **Baccalaureate (liberal arts) colleges II** (450) award fewer than 40 percent of their degrees in the liberal arts and science fields and are less restrictive in admissions than baccalaureate colleges I.
- **Associate of arts colleges** (1,155) offer certificate or degree programs through the associate degree level and, with few exceptions, offer no bachelor's degrees.
- **Professional schools and other specialized institutions** (418) offer degrees ranging from bachelor's to doctoral. At least 50 percent of the degrees awarded by these institutions are in a single specialized field. Institutions include theological seminaries, Bible colleges, and other institutions offering degrees in religion; medical schools and centers; other health profession schools; law schools; engineering and technology schools; business and management schools; art, music, and design schools; teachers' colleges; and corporate-sponsored institutions.

* The number of institutions is given in parentheses. For the number of institutions that award science and engineering degrees, by degree level and institution type, see appendix table 2-4.

Figure 2-4.
Enrollment in U.S. higher education, by institution type: 1967–97



NOTE: Enrollment data include part-time students.

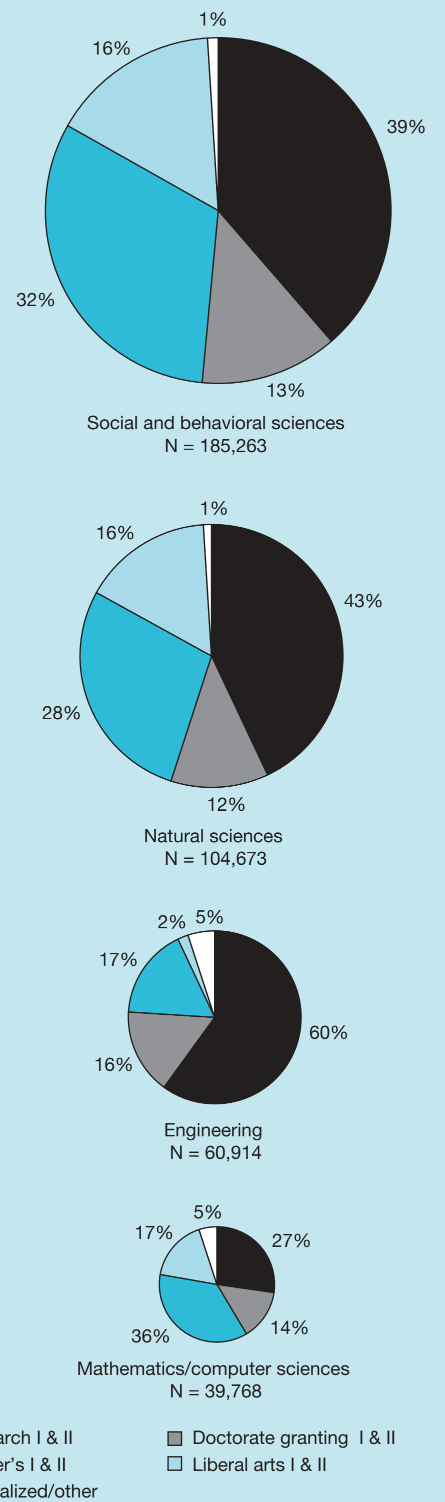
See appendix table 2-3. *Science & Engineering Indicators – 2002*

associate degrees, serve as a bridge for students to attend four-year colleges, offer an array of remedial courses and services, and enroll millions of students in noncredit and workforce training classes (Bailey and Averianova 1999). Community colleges are an accessible and low-cost group of institutions for lifelong learning. In 1998, 63 percent of the students in community colleges were enrolled part time, and more than 60 percent of these part-time students were older than age 25; in general, enrollment in remedial courses includes a significant number of older adults taking refresher courses (Phillippe and Patton 1999; American Association of Community Colleges 2001).

The role of community colleges as a bridge to four-year schools is difficult to determine because many students transfer to four-year schools before earning an associate degree.

Approximately 25 percent of community college students transfer to four-year institutions, but percentages differ by field and by state. Eighteen percent of physical science students attending four-year schools in 1994 had previously attended a community college, and 15 percent of those earning bachelor's degrees in computer sciences in 1994 had also earned associate degrees (U.S. Department of Education 1998). In Indiana, 67 percent of teachers surveyed took community college courses as part of their formal education. Some

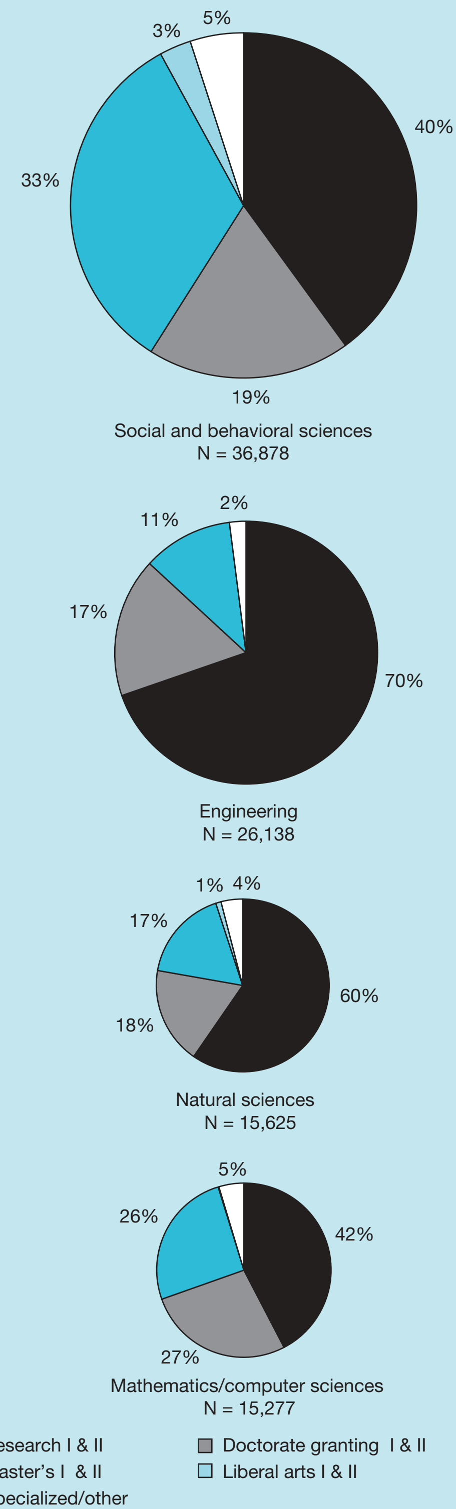
Figure 2-5.
Bachelor's degrees awarded in S&E, by institution type: 1998



NOTE: Natural sciences include physics, chemistry, astronomy, earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix table 2-4. *Science & Engineering Indicators – 2002*

Figure 2-6.
Master's degrees awarded in S&E, by institution type: 1998



NOTE: Natural sciences include physics, chemistry, astronomy, earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix table 2-4. *Science & Engineering Indicators – 2002*

states encourage students to begin a bachelor's program at a community college: 50 percent of students in the California State University system attended a community college before entering a bachelor's degree program at a four-year institution. In addition, 75 percent of upper division education majors in the California State University system began their studies at community colleges (American Association of Community Colleges 2001; Pierce 2000; and Chancellor's Office 1999).

Text table 2-1.
Distribution of faculty employment status by type of institution: 1999
(Percentages)

Institution type	Full time	Part time
All institutions	57	43
Research		
Public	79	21
Private	69	31
Doctoral		
Public	72	28
Private	49	51
Master's		
Public	64	36
Private	50	50
Liberal arts, private	63	37
Two-year, public	35	65
Other	53	47

NOTE: Faculty includes all instructional staff.

SOURCE: U.S. Department of Education, National Center for Education Statistics, "1999 National Study of Postsecondary Faculty" (Washington, DC, 2001).

Science & Engineering Indicators – 2002

Of all students in higher education in 1997, minority populations were concentrated in community colleges as follows: 46 percent of Asians/Pacific Islanders, 46 percent of blacks, 55 percent of Hispanics, and 55 percent of American Indians/Alaskan Natives (Phillippe and Patton 1999). A recent study indicates that minority students attending community colleges are more likely to transfer to selective four-year institutions than their colleagues who begin their academic career at a four-year school. Also, the completion rate for these transfer students is comparable with that of transfer students from other colleges (Eide, Goldhaber, and Hilmer, forthcoming).

The importance of community colleges in advancing the nation's technical workforce is indicated by the number of associate degrees and certificates in S&E fields and the number of information technology (IT) workers reporting "some" college experience. See sidebar, "Role of Community Colleges in Expanding Supply of Information Technology Workers."

New Modes of Delivery

The number of earned degrees from traditional institutions does not adequately represent the knowledge being acquired by students in science, engineering, mathematics, and computer sciences in a given year. Lifelong learning and various new ways of acquiring knowledge are not all quantified or captured in current education indicators. No indicators ad-

Text table 2-2.
Postsecondary faculty in S&E, by race/ethnicity, field, and employment status: 1999
(Percentages)

Race/ethnicity and field	Full time		Part time,
	2-year institutions	4-year institutions	4-year institutions
White			
Natural sciences and mathematics	82.4	83.3	80.8
Life sciences	88.5	85.0	91.4
Social and behavioral sciences	80.6	86.1	86.6
Engineering and computer sciences	85.4	80.5	82.7
Asian/Pacific Islander			
Natural sciences and mathematics	3.8	10.9	5.6
Life sciences	4.9	9.7	6.0
Social sciences	1.8	4.8	2.2
Engineering and computer sciences	4.9	13.5	7.2
Underrepresented minorities			
Natural sciences and mathematics	13.9	5.8	13.7
Life sciences	6.6	5.3	2.7
Social sciences	17.6	9.1	11.2
Engineering and computer sciences	9.7	6.0	10.0

NOTE: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, and ocean sciences.

SOURCE: U.S. Department of Education, National Center for Education Statistics, "1999 National Study of Postsecondary Faculty" (Washington, DC, 2001).

Science & Engineering Indicators – 2002

Role of Community Colleges in Expanding Supply of Information Technology Workers

A recent study on the educational background of the expanding information technology (IT) workforce indicates that the contribution of associate degree holders to that pool has declined. The number of IT workers with associate degrees newly entering the workforce (IT workers 25–34 years of age) declined by more than 20 percent from 1994 to 1999. (See text table 2-3.) However, case studies of selected community colleges (American River in Sacramento, California, and Bellevue in Bellevue, Washington) show other contributions of these institutions to the nation's IT workforce (Lerman, Riegg, and Salzman 2000).

Enrollment in IT classes at these institutions continues to grow, as does the proportion of workers reporting that they have some college background but lack a formal degree. Between 1994 and 1999, the number of IT workers who had "some college" experience but no degree increased by about 43 percent. (See text table 2-3.) Although there is no way to know where the "some" college group is getting its schooling, IT workers who report some college education have probably received their related education from community colleges.

Much of the information on IT education contributed by community colleges does not appear in the statistics on IT-related associate degrees and certificates. Many students leave before obtaining a degree or certificate, either because they find employment or because they already have a four-year degree and are not concerned with an associate degree or a certificate. At Bellevue Community College in 1998, 827 students were enrolled in IT programs, but only 67 graduated with associate degrees and 21 graduated with certificates. The lack of interest in obtaining a degree may partly reflect the fact that many (198) Bellevue IT students (24 percent of the total IT enrollees) had already earned a four-year degree. Interviews with faculty indicate that 85 percent of students who left their institutions without a degree or certificate were employed. The colleges reported that almost one-third of all IT program participants between 1994 and 1997 left before completing even 10 class credits (Lerman, Riegg, and Salzman 2000).

Text table 2-3.
IT workforce, by education and age: 1994 and 1999

Education and age	1994 Number	1994 Percent	1999 Number	1999 Percent
Total, all IT workers	1,668,000	100.0	2,347,000	100.0
Less than high school graduate	11,000	0.7	12,000	0.5
High school graduate	141,000	8.5	195,000	8.3
Some college	267,000	16.0	381,000	16.2
Associate of arts	182,000	10.9	205,000	8.9
Bachelor's degree	793,000	47.5	1,143,000	48.7
Graduate degree	274,000	16.4	411,000	17.5
25- to 34-year-old IT workers	702,000	100.0	880,000	100.0
Less than high school graduate	3,000	0.4	4,000	0.5
High school graduate	49,000	7.0	48,000	5.5
Some college	76,000	10.8	125,000	14.2
Associate of arts	85,000	12.1	67,000	7.6
Bachelor's degree	386,000	55.0	466,000	53.0
Graduate degree	103,000	14.7	170,000	19.3

SOURCE: R.I. Lerman, S.K. Riegg, and H. Salzman, "The Role of Community Colleges in Expanding the Supply of Information Technology Workers" (Washington, DC, The Urban Institute, 2000).

Science & Engineering Indicators – 2002

equately capture the nontraditional education acquired through industrial training, certificate programs, and distance learning. See sidebars, "New Horizons in Science and Engineering Education" and "Certificate Programs."

Limited data exist on student participation and completion rates for many of the cited mechanisms. For example, national education surveys do not capture the number and types of students enrolled in most certificate programs or those taking an array of related courses that could lead to upgraded job skills but not a formal degree. Such data are needed to gain a more complete picture of the nation's S&E education and training system.

New Horizons in Science and Engineering Education

The advent of technologies that support distance education and the demands of science and engineering (S&E)-related business and industry (e.g., information technology (IT) and bioinformatics) have been accompanied by the development of alternative mechanisms of delivering higher education, such as industrial learning centers and distance education. An increasing number of people are taking advantage of these alternatives either to enter new fields or to upgrade their skills in existing but rapidly changing fields. Many of the mechanisms, whether offered through traditional institutions (whose data are captured in national education surveys) or outside those institutions, could be defined as within the realms of continuing education or workplace training.

Industrial Learning Centers

Currently, approximately 2,000 industrial learning centers exist in the United States (compared with 400 in 1986), and this number will likely continue to increase rapidly. In general, these centers serve employees within a specific company or industry and are business management oriented. Some large industries, however, have internal training at the level of higher education in engineering and design. For example, the so-called "Motorola University" has an annual $2 billion budget (similar to that of the University of Indiana and Purdue University) and contracts with 1,200 faculty worldwide. These faculty teach business and engineering wherever Motorola is designing innovative products

Many industrial centers are partnered with traditional institutions of higher education and use traditional courses and university faculty to supplement industry-developed training courses (Meister 2001). For example, Motorola University has partnerships with traditional institutions for sharing technology, faculty, and facilities. Motorola is part of a Ph.D. program at the Indian Institute of Information Technology (IIIT) in Hyderabad, India, and degree programs at Morehouse University in Atlanta and Roosevelt University in Chicago. At the associate level, Motorola University works with faculty from Pretoria University's engineering school in South Africa (Wiggenhorn 2000).

Distance Education

Distance education is a rapidly growing and relatively unregulated aspect of higher education. In 2001, the Regional Accrediting Commissions issued their first set of guidelines for the evaluation of electronically offered degree and certificate programs (Regional Accrediting Commissions 2001). Comprehensive data are not available on the number of undergraduate and graduate S&E degrees or the number of programs fully or partially offered through distance education. However, interest in delivering and taking S&E courses and entire programs via distance education is growing (Office of Government and Public Affairs 2000). In 1997, more than 50,000 different on-line courses were offered by postsecondary institutions; 91 percent were college-level credit courses. Approximately 1.6 million people registered for on-line courses in 1998, 82 percent in college-level credit courses at the undergraduate level (University Continuing Education Association 2000). In many ways, these programs are comparable to correspondence programs offered either by for-profit institutions, such as the International Correspondence Schools, or by traditional universities through their correspondence or continuing education units. In IT-related certification programs, this method of delivering postsecondary education may be one of the dominant modes, at least on an international basis.

Undergraduate S&E Students and Degrees in the United States

Key challenges for undergraduate education in S&E include preparing teachers for K–12 and college levels (Committee on Science and Mathematics Teacher Preparation (CSMTP) 2001), preparing scientists and engineers to fill needed workforce requirements and provide the capacity for long-term innovation (Romer 2000; NSTC 2000), providing understanding of basic science and mathematics concepts for all students, and measuring what students learn (National Center for Public Policy and Higher Education 2000). These challenges relate to the nation's ability to retain its innovation capacity and international position in S&T.

The need for undergraduate teaching that could attract and retain students in S&E fields has been widely noted and discussed (National Commission on Mathematics and Science Teaching for the 21st Century 2000). Professional associations (Gaff et al. 2000; Sigma Xi 1999), private foundations (Kellogg Commission on the Future of State and Land-Grant Universities 1997), public officials (National Governors Association 2001), and universities themselves (NSF/EHR Advisory Committee 1998) have each expressed concern regarding the delivery of undergraduate education.

The nation must also meet its growing need for K–12 teachers, particularly in mathematics and science. Recent studies indicate that in the upcoming decade, the nation's school districts will need to hire 2.2 million new teachers (U.S. Department of Education 1999), including 240,000 middle and high school mathematics and science teachers (National Commission on Mathematics and Science Teach-

Certificate Programs

Three types of certificate programs are described below, based on mode of delivery (i.e., university based, community college based, or exam based).

University Based

A recent survey by the Council of Graduate Schools revealed that of the 179 university-based certificate programs reported, 34 percent were in engineering-, health-, or science-related fields, and 15 percent were in computing (Patterson 1999, 1998). The council is considering mechanisms for accrediting these university-based certificate programs and has divided them into three categories:

- **Specialty**—do not require a prior degree, are typically narrow in scope, and are oriented toward nontraditional students hoping to develop or upgrade career-related skills.
- **Professional**—require a prior degree and are typically designed to upgrade the licensure of professionals such as nurses or social workers.
- **Graduate**—augment and broaden skills and knowledge acquired through graduate degrees in the traditional disciplines and are typically interdisciplinary in scope (e.g., a graduate certificate program in environmental ethics).

Community College Based

Community colleges are an important source of science and engineering-related certification programs. (See text table 2-4.) The importance of community colleges as sources of information technology (IT)-related certificates can be estimated from the distribution of academic providers authorized by Microsoft in August 2000. Of 650 total providers, 46 percent (298) are listed as being at community colleges or two-year schools (either public/not for profit or for profit) (U.S. Department of Education 2000). (See text table 2-5.)

Exam Based

These certificates are earned by passing skill-based examinations offered globally and do not always require formal coursework, although applicants may elect to take related courses. To prove continuous updating of skills, some levels of certification require applicants to pass exams based on advances in the field. In the field of IT, for example, in 1999, 5,000 sites in 140 countries were administering an estimated 3 million assessments in 25 languages. The growth of this type of certificate for the IT industry has been rapid. More than 300 discrete certifications have been established since 1989, when the first IT certificate (Certified Novell Engineer) was issued. Approximately 1.6 million individuals worldwide earned approximately 2.4 million IT certificates by early 2000, mostly after 1997; more than 50 percent of these certificates were earned outside the United States. The exams are administered by one of three corporations (Prometric, CatGlobal, and Virtual University Enterprises), but the courses often are offered by vendors related to or licensed by the corporations whose systems are designated on the certificates (e.g., Microsoft, Cisco, Oracle, or Novell) (U.S. Department of Education 2000).

Text table 2-4.
Certificates conferred by community colleges, by field and duration: 1996–97

Field	Total	<1 year	1–2 years	>2 years
Total	166,776	69,400	85,745	11,631
S&E	60,296	24,953	32,470	2,873
Health and related sciences	56,659	23,401	30,585	2,673
Computer and information sciences	3,423	1,506	1,723	194
Other S&E-related fields	214	46	162	6
Non-S&E	106,480	44,447	53,275	8,758
Science technologies	137	78	53	6
Engineering technologies	6,203	1,705	3,705	793

SOURCE: K.A. Phillippe and M. Patton, *National Profile of Community Colleges: Trends & Statistics*, 3d ed. (Washington, DC, Community College Press, American Association of Community Colleges, 1999).

Science & Engineering Indicators – 2002

Text table 2-5.
Microsoft-authorized academic training providers, by level and control: 2000

Level and control	Number	Comment
Four-year public and not for profit	142	Approximately one-third are continuing education units.
Four-year for profit	42	Two-thirds are campuses of the University of Phoenix.
Two-year public and not for profit	298	Includes multiple campuses of large community college districts such as Houston and Allegheny (Pittsburgh).
Indeterminable post secondary status	39	Not listed in Barbett and Lin (1998) or otherwise located.
High schools	129	More than half are technical/vocational high schools.

SOURCE: U.S. Department of Education, Office of Educational Research and Improvement, *A Parallel Postsecondary Universe: The Certification System in Information Technology*, by C. Adelman (Washington, DC, 2000).

Science & Engineering Indicators – 2002

ing 2000). Of the total, 70 percent will be new to the profession, as teachers retire and the student population increases. The need for new teachers also reflects changes in course-taking patterns; student demand for high-level mathematics and science courses in high school is increasing. In addition, the need to improve teacher preparation is reflected in the number of teachers teaching in fields other than those for which they were prepared. For example, 20 percent of the middle and high school mathematics teachers hired during the 1993/94 academic year were not certified to teach mathematics (Blank and Langesen 1999). See chapter 1, “Elementary and Secondary Education,” for the magnitude of the problem of teachers teaching out of field.

Workplace needs are changing in our information- and service-oriented economy. The workforce requires people competent in mathematics, S&E, critical thinking, and the ability to work in teams (NSTC 2000). Availability of high-level, diverse personnel for basic research, discovery, and innovation depends on a sufficient pool of well-prepared students with bachelor’s degrees who are willing and able to persist through doctoral education.

The growing pressure for accountability calls for measuring the value of higher education by what students learn rather than by campus offerings. A recent study of higher education efforts found all states in the nation deficient in this area (National Center for Public Policy and Higher Education 2000).

This section gives indicators related to some of these challenges, particularly the challenge of preparing a diverse S&E workforce. These indicators include the growing diversity in undergraduate enrollment and intentions to major in S&E fields, the relatively low completion rates of S&E degrees among underrepresented minority students, the need for remediation at the college level, and recent declining trends in the number of earned degrees in most S&E fields. The section also includes recommended reforms to meet the challenges of preparing teachers and measuring student learning and describes programs showing initial signs of success.

Enrollment and Retention in S&E

Undergraduate Enrollment by Sex and Race/Ethnicity

The U.S. college-age population has grown since 1997, and the percentage of high school graduates enrolling in college is increasing for some groups. By 1999, approximately 45 percent of white and 39 percent of black high school graduates were enrolled in college, up from approximately 31 and 29 percent, respectively, in 1979. (See text table 2-6.) However, during this period, enrollment rates in higher education for Hispanic high school graduates increased only slightly, from 30 to 32 percent. An even greater racial/ethnic disparity exists with respect to Hispanic college enrollment rates based on the total college-age population (including students who did not complete high school or those who recently immigrated to the United States with little education) (Tienda and Simonelli 2001).

In the past two decades, the proportion of white students in U.S. undergraduate enrollment decreased, falling from 80 percent in 1978 to 70 percent in 1997. The proportion of underrepresented minorities increased the most, from 15.7 to 21.7 percent. Asians/Pacific Islanders increased from 2.0 to 5.8 percent, and foreign students remained approximately 2 percent of undergraduate enrollment. Women outnumber men in undergraduate enrollment for every race and ethnic group. White women constitute 55 percent of white undergraduate students, and black women constitute 62 percent of black undergraduate enrollment, which is the greatest difference found among racial groups. (See appendix table 2-8.)

Engineering Enrollment

Generally, engineering programs require students to declare their major in the first year of college, which makes enrollment an early indicator of undergraduate engineering degrees and interest in engineering careers. The annual fall

Text table 2-6.
Enrollment rates of high school graduates in higher education, by race/ethnicity: 1979–99

Race/ethnicity	1979	1989	1999
Total	31.2	38.1	43.7
White	31.3	39.8	45.3
Black	29.4	30.7	39.2
Hispanic	30.2	28.7	31.6

NOTE: Data are enrollment as a percentage of all 18- to 24-year-old high school graduates.

See appendix table 2-7. *Science & Engineering Indicators – 2002*

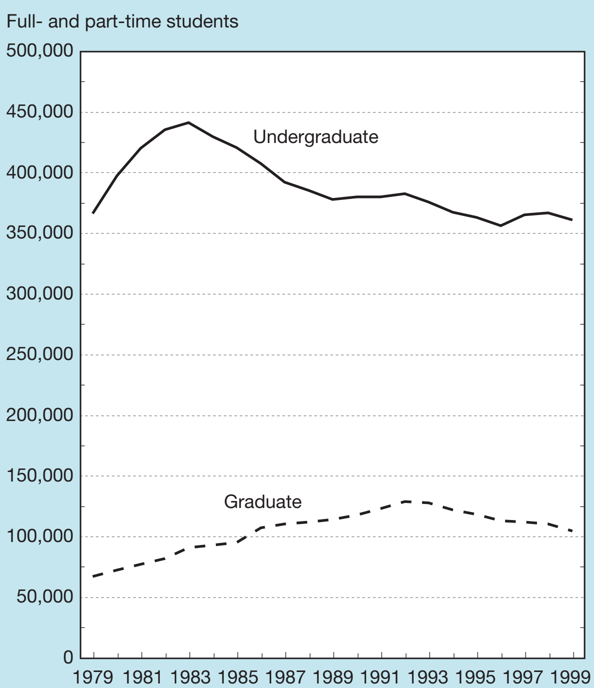
survey of the Engineering Workforce Commission (2000) obtains data on actual enrollment in graduate and undergraduate programs.

The long-term trend has been for fewer students to enter engineering programs. From 1983 to 1990, engineering enrollment decreased sharply, followed by fluctuating and slower declines in the 1990s. Trends differ by degree level. At the bachelor's degree level, undergraduate enrollment declined by more than 20 percent from 441,000 students in 1983 (the peak year) to 361,000 students in 1999. (See figure 2-7 and appendix table 2-9.) At the associate degree level, enrollment in engineering technology dropped precipitously from 1998 to 1999. The number of first- and second-year students enrolling in such programs declined by 25 and 36 percent, respectively. This associate degree level of engineering technology may be shifting somewhat to workplace training. Graduate engineering enrollment peaked in 1993 and has continued downward since. (See appendix table 2-10.)

Freshmen Intentions to Major in S&E

Whether students in the United States are interested in studying S&E fields is of growing concern. Whether women and minorities are attracted to S&E majors is also of national interest because together they make up the majority of the labor force, and they have traditionally not earned S&E degrees at the same rate as the male majority. Their successful completion of S&E degrees will determine whether there will be an adequate number of entrants into the S&E workforce in the United States. Since 1972, each fall, the Higher Education Research Institute's Freshman Norms Survey asks a national sample of first-year students in four-year colleges and universities about their intentions to major in an S&E field and their readiness for college-level S&E coursework (Higher Education Research Institute (HERI) 2001). See sidebar, "Freshman Norms Survey."

Figure 2-7.
U.S. engineering enrollment, by level: 1979–99



See appendix table 2-10. *Science & Engineering Indicators – 2002*

Retention in S&E

Although approximately 25–30 percent of students entering college in the United States intend to major in S&E fields, a considerable gap exists between freshman intentions and successful completion of S&E degrees. A National Center for Educational Statistics (NCES) longitudinal study of first-year S&E students in 1990 found that fewer than 50 percent had completed an S&E degree within five years (U.S. Department of Education (NCES) 2000).[3] Students intending an S&E major in their freshman year explore and switch to other academic departments in undergraduate education, and approximately 20 percent drop out of college. The study also shows that underrepresented minorities complete S&E programs at a lower rate than other groups. A more recent longitudinal study, from 1992 to 1998, traces freshmen retention in S&E by sex, race/ethnicity, and selectivity of the institution. See sidebar, "Retention and Graduation Rates."

Associate Degrees

Trends in S&E Associate Degrees

For more than a decade, the number of associate degrees earned in S&E has fluctuated between 20,000 and 25,000. At the associate level, computer sciences represented the most sought-after S&E field; in 1998, the 13,000 computer science degrees represented 45 percent of all S&E degrees. After a five-year decline from the peak year of 1986, the number of earned degrees in computer sciences increased at an average annual rate of 5.6 percent in the 1990s. Degrees earned in engineering technology (not included in S&E total degrees) are far more numerous than degrees in S&E fields; however, they have experienced a long, steady decline during the past two decades. At the associate level, the number of degrees earned in engineering technology dropped from more than 52,000 in 1981 to 33,000 in 1997, a 36 percent decline. (See appendix table 2-14.)

Associate Degrees by Race/Ethnicity

Trends in the number of associate degrees earned by minority students differ from overall trends. Among Asians/Pacific Islanders, growth in the number of earned computer science degrees occurred during the past several years, from 1995 to 1998; the declining trend in engineering technology was neither as continuous nor as long. Among blacks, the number of degrees earned in engineering technology remained approximately 3,000 per year for the past decade, and degrees earned in computer sciences increased slightly from 1989 to 1997, with strong growth in 1998. Trends among Hispanics showed increases in the number of degrees earned in engineer-

[3]A longitudinal study follows the same students for several years.

Freshman Norms Survey

The Freshman Norms trend data show that freshmen of every race and ethnicity have high aspirations to study science or engineering (HERI 2001). For the past few decades, approximately 30 percent of white freshmen reported their intention to major in science, engineering, mathematics, or computer sciences; a higher percentage of Asian American students intended to pursue such a major (40–50 percent). In the 1990s, more than one-third of freshmen in underrepresented minority groups intended to major in science and engineering (S&E) fields. The proportion was higher for men in every racial/ethnic group and lower for women. In the 1990s, men in every group reported increased interest in computer sciences. (See appendix table 2-11.)

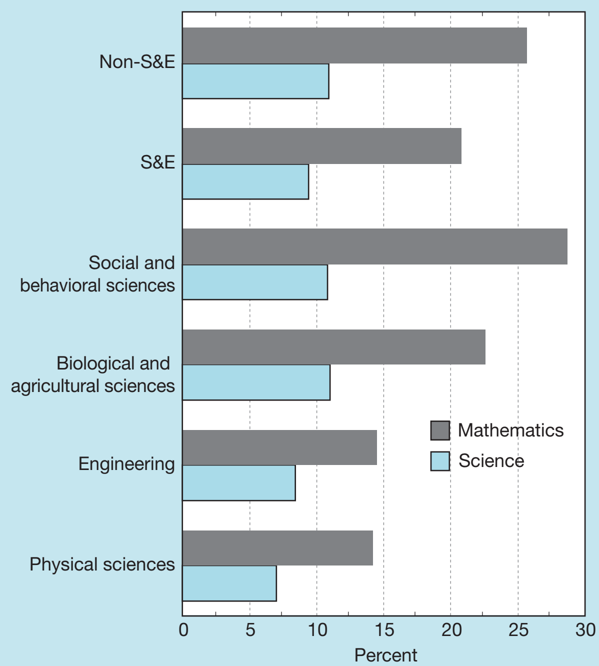
By 2000, women constituted 44 percent of the first-year college students reporting intentions to major in S&E; 56 percent were men. The data also show increasing racial diversity among freshmen intending to choose an S&E major. By 2000, underrepresented minority groups represented more than 20 percent of those intending to choose an S&E major,* up from 8 percent in 1971. The general trend is an increasing proportion of black and Hispanic freshmen among students intending to pursue a natural science or engineering major. (See appendix table 2-12.) For example, from 1986 to 2000, the proportion of underrepresented minorities intending to major in biological sciences or engineering rose from approximately 10 to 18 percent of first-year college students.† During the same period, 22–23 percent of underrepresented minority students intended to major in computer sciences, but the proportion intending to study mathematics and statistics declined from 12 to 8 percent. (See appendix table 2-12.)

*In 2000, white students constituted 66 percent of the 18- to 24-year-old population in the United States; underrepresented minority groups constituted 30 percent. (See appendix table 2-2.)

†Underrepresented minority students are not uniformly distributed across all institutions, however. They are more concentrated in minority-serving institutions: comprehensive universities and liberal arts colleges, tribal colleges, and historically black colleges and universities.

Are freshmen in the United States ready for college-level coursework? In 2000, more than 20 percent of first-year college students intending to undertake an S&E major reported that they needed remedial work in mathematics; almost 10 percent reported they needed remedial work in the sciences. This percentage has been relatively stable during the past 25 years. (See appendix table 2-13 and *S&E Indicators–2000*, appendix table 2-12.) There are some differences, however, by field of intended major. Students intending to major in the physical sciences and engineering report a lesser need for remedial work than students in other fields. In contrast, students intending to major in social and biological sciences, as well as in non-S&E fields, report more need for remedial work. (See figure 2-8.)

Figure 2-8.
Freshmen reporting need for remedial work in science or mathematics, by intended major: 2000



See appendix table 2-13. *Science & Engineering Indicators – 2002*

ing technology until 1995, followed by three consecutive years of decline and strong growth in computer sciences in the 1990s but from a low base. The number of degrees earned by American Indians/Alaskan Natives increased in all S&E fields from a very low base in 1985. (See appendix table 2-15.)

Although the proportion of degrees earned by students from underrepresented minority groups continues to increase slightly at all levels of higher education, the proportion of degrees earned at the associate level by these groups is considerably higher than that at the bachelor's or more advanced levels. The proportion of social science degrees earned by these groups at the associate level has traditionally been high (25–28 percent), and the proportion of computer science degrees earned by these students has almost doubled since 1985. (See appendix table 2-15.) In 1998, these students earned approximately 23 percent of the mathematics and computer science degrees at the associate level, a far higher percentage than at the bachelor's or more advanced levels of higher education. At the advanced levels, the percentage of S&E degrees earned by underrepresented minorities drops off,

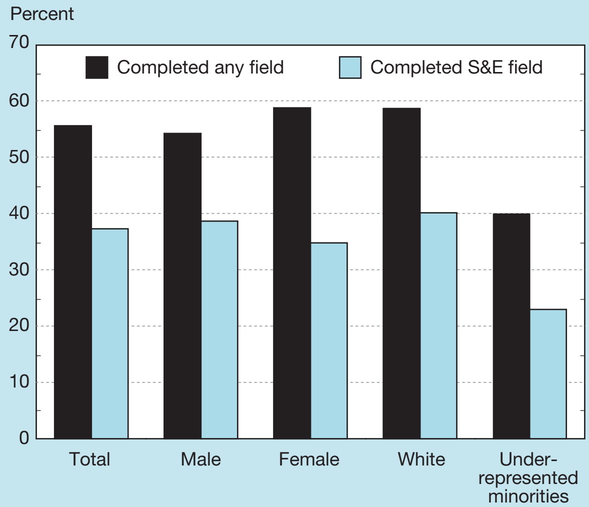
Retention and Graduation Rates

The Center for Institutional Data Analysis and Exchange (C-IDEA 2000) at the University of Oklahoma recently released a report of its longitudinal study, conducted from 1992 to 1998, of a cohort of college students. The study aimed to gather benchmark statistics on retention rates in science, mathematics, engineering, and technology disciplines. The study surveyed 119 colleges and universities ranging from small to large, liberal admission to highly selective admission, and bachelor's degree–only to doctorate-granting institutions.

In 119 colleges and universities, about 25 percent of all entering first-time freshmen in 1992 declared their intention to major in a science and engineering (S&E) field. By their second year, 33 percent of these students had dropped out of an S&E program. After six years, 38 percent had completed an S&E degree. Women and underrepresented minorities dropped out of S&E programs at a higher rate than men and nonminority students. Consequently, degree completion rates in S&E fields were lower for women (35 percent) and underrepresented minorities (24 percent). (See figure 2-9.)

The study found that retention rates of S&E majors also differ by institution. Specifically, retention rates are higher at more selective institutions, institutions with fewer part-time undergraduate students, and research institutions that also award postgraduate (master's and doctoral) degrees.

Figure 2-9.
Graduation rates and S&E completion rates of 1992 freshmen intending S&E major, by sex and race/ethnicity



NOTES: Study covers first-time college freshmen with intentions to major in S&E fields entering in 1992 and completing bachelor's degree by 1998. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native.

SOURCE: Center for Institutional Data Exchange and Analysis, *1999–2000 SMET Retention Report*, University of Oklahoma (2000).

Science & Engineering Indicators – 2002

particularly in natural sciences and engineering (NS&E). In contrast, the decline in the percentage of degrees earned by underrepresented minorities at the advanced levels is smaller in social sciences and non-S&E fields. (See figure 2-10.)

Bachelor's Degrees

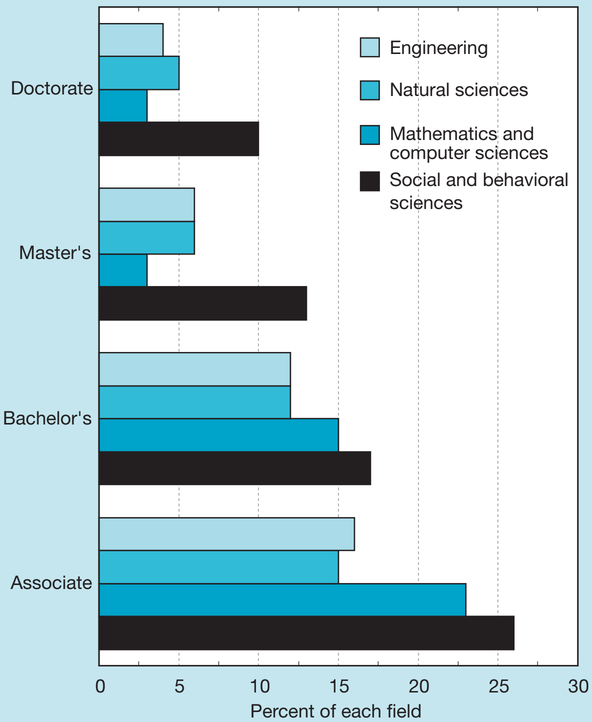
Percentage of Bachelor's Degrees in S&E Fields

Are college students earning the same percentage of bachelor's degrees in S&E fields as in the past, or have more students switched to non-S&E fields? From 1975 to 1998, the ratio of overall S&E degrees to total degrees remained approximately 33 percent. The percentages in fields within S&E, however, shifted during this period. In 1986, the year in which most S&E degrees were earned, engineering represented 8 percent of all bachelor's degrees earned, followed by a long, slow decline to 5 percent in 1998 (NSF/SRS 2001c). Since 1986, the percentage of bachelor's degrees earned by undergraduates has also declined slightly in physical sciences, mathematics, and computer sciences. In contrast, since 1986, the percentage of bachelor's degrees awarded in social and behavioral sciences and in biological sciences has increased. (See text table 2-7.)

Degree Trends

The number of overall S&E bachelor's degrees increased in the past two decades and leveled off in the late 1990s. However, the composite rise represents divergent trends in various fields. Biological and agricultural sciences are the only fields that show continuous increases in the number of degrees earned throughout the 1990s. Trends in biological sciences show a long, slow decline in the number of degrees earned in the 1980s but indicate a reversal of this trend in the early 1990s, which continued throughout the decade. The number of degrees earned in psychology increased in the 1990s but leveled off in 1997. In all other S&E fields, the number of degrees earned was either stable or declined. For two decades, students earned a relatively stable number of degrees in the physical sciences and mathematics, with slight declines in mathematics in the past few years. The number of degrees earned in computer sciences peaked in 1986, declined until the early 1990s, and then fluctuated in that decade, with a slight increase in 1997–98. The number of degrees earned in social sciences strongly increased in the 1980s, peaked in 1993, and then declined and leveled off. The number of engineering degrees earned peaked in 1986, declined sharply until 1990, fluctuated within that decade, and declined again in 1998. (See NSF/SRS 2001c and figure 2-11.)

Figure 2-10.
S&E degrees earned by underrepresented minorities within each field, by level: 1998–99



NOTES: Doctoral-level degrees are 1999 data; all other levels use 1998 data. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native.

See appendix tables 2-15, 2-17, 2-23, and 2-25.

Science & Engineering Indicators – 2002

Text table 2-7.
Bachelor's degrees earned in S&E fields: various years
(Percentages)

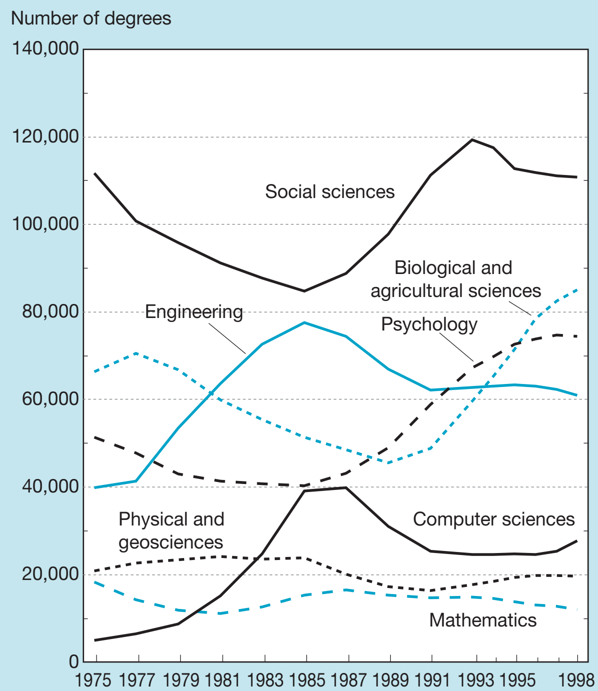
Field	1975	1985	1998
All S&E[a]	33.7	33.5	32.6
NS&E	16.1	20.9	17.1
Physical sciences	1.7	1.6	1.3
Earth, atmospheric, and ocean sciences	0.5	0.8	0.4
Biological and agricultural sciences	7.1	5.2	7.1
Mathematics	2.0	1.6	1.0
Computer sciences	0.5	3.9	2.3
Engineering	4.3	7.8	5.1
Social and behavioral sciences	17.5	12.6	15.4

NS&E = natural science and engineering

[a]Percentage of all bachelor's degrees.

See appendix table 2-16. *Science & Engineering Indicators – 2002*

Figure 2-11.
Bachelor's degrees earned in selected S&E fields: 1975–98



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-16. *Science & Engineering Indicators – 2002*

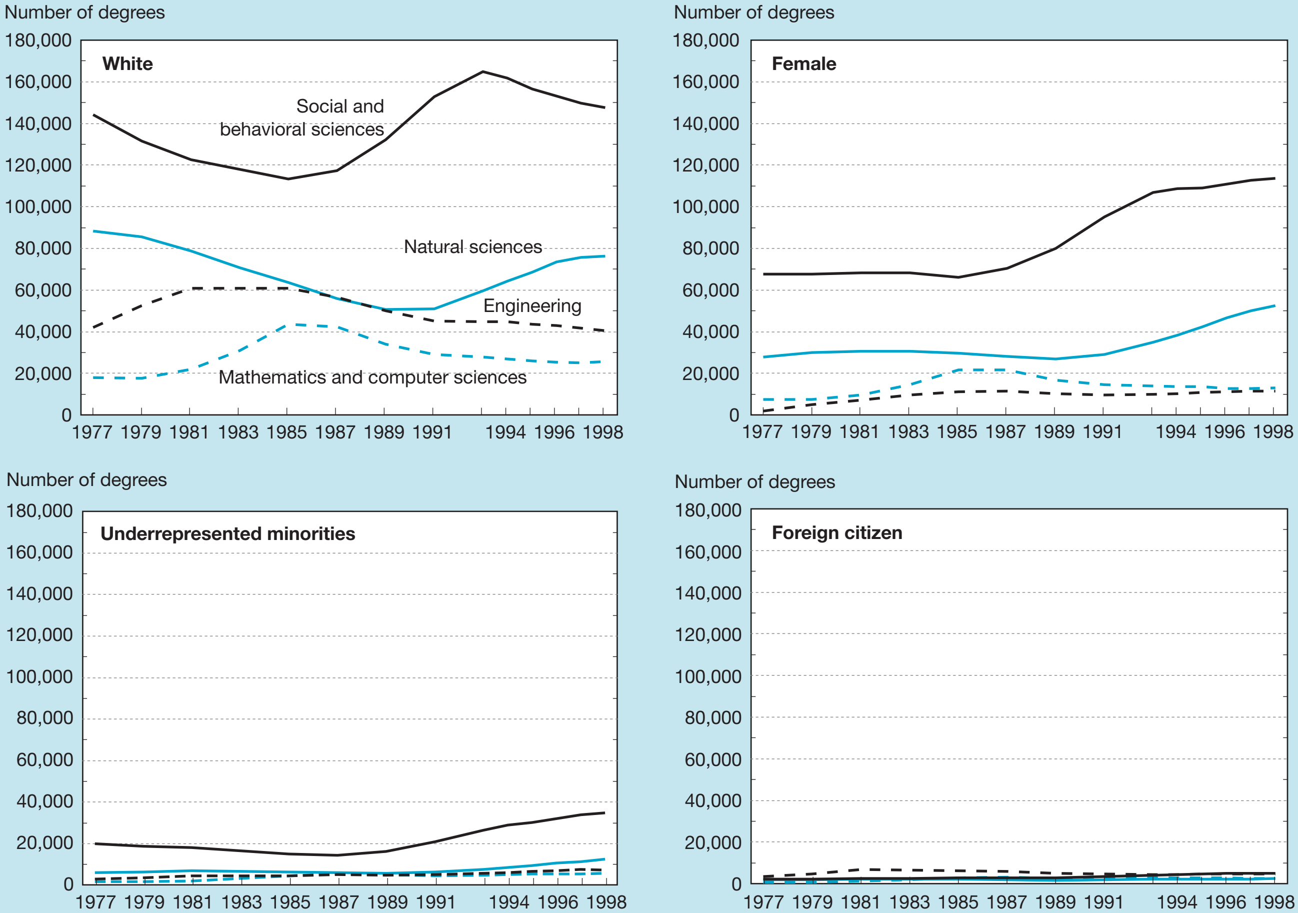
Bachelor's Degrees by Sex

The rise in the number of degrees earned in biological sciences and psychology in the 1990s reflects a high proportion of women entering these fields (48 percent in biological sciences and 72 percent in psychology in 1998), thus offsetting the decline expected from the shrinking college-age cohort. The declining number of degrees earned in most other S&E fields is influenced by both the shrinking college-age cohort and an underrepresentation of women and minorities in these fields. Women and minorities continue to be underrepresented in engineering and computer sciences. (See appendix table 2-16.) The sharp decline in the number of degrees earned in computer sciences is probably a combination of demographics and other readily available (non-degree-granting) modes of acquiring skills in this field, such as workplace training, certificate programs, and on-line courses. See sidebars, "New Horizons in Science and Engineering Education" and "Certificate Programs." (See appendix table 2-1.)

Bachelor's Degrees by Race/Ethnicity

In contrast to overall trends, all minority groups showed an increasing or stable number of degrees earned in most S&E fields in the 1990s. The number of degrees earned by Asians/Pacific Islanders increased in all S&E fields except mathematics. Underrepresented minority groups show a stable number of degrees earned in physical sciences, mathematics, and computer sciences and decade-long increases in degrees earned in social and behavioral sciences, biological sciences, and engineering. In 1998, their number of degrees earned lev-

Figure 2-12.
Bachelor's degrees in S&E fields, earned by selected groups



NOTES: Data for 1983 are estimated. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native. White and underrepresented minorities include U.S. citizens and permanent residents. Foreign citizen includes temporary residents.

See appendix tables 2-16 and 2-17.

Science & Engineering Indicators – 2002

eled off only in engineering, after a decade-long increase. (See appendix table 2-17 for data by field and figure 2-12 for degree trends of selected groups.)

Bachelor's Degrees by Citizenship

Foreign students earn a small percentage (3.6 percent) of S&E bachelor's degrees, a number barely visible on a graph. (See figure 2-12.) Trends in degrees earned by foreign students show increases in the number of bachelor's degrees in social sciences, with slight increases in biological sciences and psychology; fluctuating and declining degrees in engineering; and declining degrees in physical sciences, mathematics, and computer sciences. Foreign students in U.S. institutions earn approximately 7–8 percent of bachelor's degrees awarded in mathematics, computer sciences, and engineering—somewhat lower than the proportion of degrees earned by foreign students in U.K. institutions. In 1999, foreign students in U.K. universities earned almost 30 percent of the bachelor's degrees awarded in engineering and 12 percent of those awarded in mathematics and computer sciences. (See text table 2-8.)

U.S. Participation Rates in Bachelor's Degrees and S&E Degrees by Sex and Race/Ethnicity

Traditionally, the United States has been among the leading nations of the world in providing broad access to higher education. The ratio of bachelor's degrees earned in the United States to the population of the college-age cohort is relatively high: 35 per 100 in 1998. The ratio of natural science and engineering (NS&E) degrees to the population of 24-year-olds in the United States has been between 4 and 5 per 100 for the past several decades and reached 6 per 100 in 1998. Several Asian and European countries have higher participation rates. (See appendix table 2-18 and "International Comparison of Participation Rates in University Degrees and S&E Degrees.")

Text table 2-8.
Bachelor's degrees earned by foreign students in S&E fields, United Kingdom and United States

Field	Degrees: All students	Degrees: Foreign students	Percent foreign
United Kingdom (1999)			
Total S&E degrees	89,520	12,584	14.1
Natural sciences	32,226	2,223	6.9
Mathematics and computer sciences	14,630	1,708	11.7
Social and behavioral sciences	20,652	2,082	10.0
Engineering	22,012	6,571	29.9
United States (1998)			
Total S&E degrees	411,286	14,728	3.6
Natural sciences	104,852	2,391	2.3
Mathematics and computer sciences	39,404	2,585	6.6
Social and behavioral sciences	206,160	5,109	2.5
Engineering	60,870	4,643	7.6

NOTES: U.S. data on foreign students include temporary residents only. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

SOURCES: United Kingdom—Higher Education Statistics Agency, unpublished tabulations (2001); and United States—appendix table 2-17.

Science & Engineering Indicators – 2002

National statistics on participation rates in S&E fields, however, are not applicable to all minority groups in the United States. The gap in educational attainment between whites and racial/ethnic minorities continues to be wide, particularly in participation rates in S&E fields. In 1998, the ratio of college degrees earned by underrepresented minorities to their college-age populations was 18 per 100, and the ratio of NS&E degrees was 2.6 per 100. Comparison of participation rates in 1980 and 1998 shows considerable progress for underrepresented minority groups in earning bachelor's degrees, but their rate of earning NS&E degrees is still less than one-half the rate of the total population. (See text table 2-9.) In contrast, Asians/Pacific Islanders have considerably higher-than-average achievement: the ratio of bachelor's degrees earned to the college-age population is 47 per 100 and that of NS&E degrees to the college-age population is 14.7 per 100.

One partial explanation given for this gap in educational attainment is that the cost barrier for students from low-income families to attend college is increasing; the needs-based system of financial aid for college students has shifted to a greater reliance on loans, tuition tax credits, and merit-based scholarships (The College Board 2000). The cost of higher education to the middle and upper income groups of the population in terms of percentage of their income consumed has not changed appreciably, whereas the percentage of income necessary for people in the lower income group to earn a college degree has risen considerably (National Governors Association (NGA) 2001).

Recommended Reforms

Recommendations have been offered for meeting the challenges of S&E higher education. They are outlined succinctly in recent studies by the National Research Council (Committee on Undergraduate Science Education 1999; CSMTP 2001) and NSF (*Shaping the Future* 1998). The recommendations relate to both institutionwide and departmental reforms:

- **Take an institutional approach to change.** The undergraduate education responsibilities of the university should be given high priority by accrediting agencies, discipline and higher education professional organizations, faculty, departments, and university administrators.
- **Give all students math and science literacy.** Postsecondary institutions should provide all students with the strong foundation in mathematics and sciences needed to function in an increasingly technologically complex world and prepare students for careers in S&E.
- **Help faculty improve their teaching.** Faculty and future faculty need to be aware of the latest research in teaching and learning, such as the benefits of incorporating student inquiry and teamwork into their regular classroom practices, collaborative and active learning, discovery- and inquiry-based courses, and incorporating real-world problems into the classroom by asking students to help frame problems and contribute solutions.
- **Increase undergraduate research.** Develop opportunities for all students to engage in undergraduate S&E-related research with particular attention to students majoring in S&E fields, students from groups traditionally underrepresented in these fields, and students preparing to be teachers. Faculty should bring the excitement of new research findings into both lower and upper division courses.
- **Expand interdisciplinary teaching.** Increase multidisciplinary perspectives in science and mathematics undergraduate programs to reflect the increased workplace

Text table 2-9.
Ratio of total bachelor's degrees and S&E bachelor's degrees to the 24-year-old population, by sex and race/ethnicity: 1980 and 1998

						Ratio to 24-year-old population		
Race/ethnicity and sex	Total 24-year-old population	Total bachelor's degrees	Natural science degrees	Social and behavioral science degrees	Engineering degrees	Bachelor's degrees	NS&E degrees	Social and behavioral science degrees
				1980				
Total	4,263,800	946,877	110,468	132,607	63,717	22.2	4.1	3.1
Sex								
Male	2,072,207	474,336	70,102	64,221	56,654	22.9	6.1	3.1
Female	2,191,593	472,541	40,366	68,386	7,063	21.6	2.2	3.1
Race/ethnicity								
White	3,457,800	807,509	100,791	122,519	60,856	23.4	4.7	3.5
Asian/Pacific Islander	64,000	18,908	3,467	2,499	3,066	29.5	10.2	3.9
Underrepresented minority	892,000	97,539	8,915	22,782	4,464	10.9	1.5	3.9
Black	545,000	60,779	4,932	16,352	2,449	11.2	1.4	3.0
Hispanic	317,200	33,167	3,646	5,748	1,820	10.5	1.7	1.8
American Indian/Alaskan Native	29,800	3,593	337	682	195	12.1	1.8	2.3
				1998				
Total	3,403,039	1,199,579	144,441	185,263	60,914	35.3	6.0	5.4
Sex								
Male	1,714,571	525,714	78,906	71,740	49,575	30.7	7.5	4.2
Female	1,688,468	673,865	65,535	113,523	11,339	39.9	4.6	6.7
Race/ethnicity								
White	2,251,292	878,018	101,967	147,707	40,533	39.0	6.3	6.6
Asian/Pacific Islander	149,413	69,988	15,001	12,565	7,002	46.8	14.7	8.4
Underrepresented minority	1,002,334	181,709	18,424	34,836	7,396	18.1	2.6	3.5
Black	473,402	95,878	9,713	18,667	3,018	20.3	2.7	3.9
Hispanic	497,620	78,125	7,881	14,719	4,125	15.7	2.4	3.0
American Indian/Alaskan Native	31,312	7,706	830	1,450	253	24.6	3.5	4.6

NS&E = natural science and engineering

NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences, as well as mathematics and computer sciences. The ratios are the number of degrees to the 24-year-old population. Population data are for U.S. residents only and exclude members of the Armed Forces living abroad.

SOURCES: U.S. Bureau of the Census, Population Division, *U.S. Population Estimates by Age, Sex, Race, and Hispanic Origin: 1980 to 1999* (Washington, DC, 2000); National Science Foundation, Science Resources Studies (NSF/SRS), *Science and Engineering Degrees 1966–1998*, NSF 01-325 (Arlington, VA, 2001); and appendix table 2-17.

Science & Engineering Indicators – 2002

emphasis on interdisciplinary approaches, such as computational chemistry and bioengineering.

- **Increase partnerships.** Include appropriate industry and other potential employers in planning curricular changes.

Several organizations have made recommendations regarding their responsibilities for preparing high-quality K–12 teachers in science and mathematics, including institutions of higher education (Association of American Universities 1999; American Association of State Colleges and Universities 1999), business groups (National Alliance of Business 2001), and professional societies (CSMTP 2001). Although the strategies to meet their responsibilities differ, their goals to establish exemplary models of teacher preparation whose success can be widely replicated and to find ways to attract additional qualified candidates to teaching are similar.

Strategies offered by research universities and state colleges and universities include the following:

- Make teacher education a top campus priority and a joint endeavor between faculty in education programs and faculty in other academic disciplines.
- Create and sustain partnerships with schools, state departments of education, informal education providers such as zoos and museums, and local businesses and industries.
- Offer undergraduate research experience to future elementary and secondary mathematics and science teachers.
- Create sound alternatives for mathematics and science majors to obtain teacher certification.

National agencies such as the Department of Education and NSF have begun funding various support programs to

Meeting the Challenge of Teacher Preparation

In 1998, the Department of Education established Teacher Quality Enhancement grants to encourage comprehensive approaches in improving the quality of teacher preparation programs. Many of these grants are five-year awards with cumulative multimillion-dollar funding. Twenty-five awards were made in fall 1999, and eight awards were made in 2000. Six of these awards were given to institutions that had already begun the process of reform under the National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) program, which was initiated in 1992.

The 32 systemic (regional in scope) and institutional (concentrated in one or a few related institutions) CETP projects awarded as of fiscal year 2000 included 250 institutions of higher education (13 percent of the projects related to doctoral degrees, 30 percent to two-year degrees, 31 percent to master's or bachelor's degrees) and 89 to public high schools.

Data collected in spring 2000 by the systemic projects reveal that 4,050 faculty and 4,979 teachers were involved in the CETP projects' efforts to produce teachers who are prepared to teach mathematics and science and to teach and use information technology. The institutions involved in the CETP program are distributed within 22 states and produce 38 percent of the teachers in the states in which they operate. Of the 15,896 1999 CETP graduates who have been tracked, 72.4 percent entered the teaching profession, and 17.7 percent were still attending school—most presumably in postbaccalaureate programs necessary for certification in their state (NSF/EHR 2000).

Evaluation of these programs has shown that, generally, the concerted efforts to improve teacher education in mathematics and science have been effective:

- Higher student achievement was measured in schools served by the Philadelphia CETP (Temple University). From 1996 to 1999, the Stanford Achievement Test (SAT-9) math and science average test scores and gains for 4th-grade classes in which CETP undergraduates taught during their practica exceeded the citywide average.

- Retention of new teachers in the Montana CETP Early Career Support project improved. The attrition rate from teaching for the more than 120 beginning teachers in the Early Career program was approximately 3 percent, far below the national average of 30 percent.

- An increase in minority teachers resulted from the efforts of the Montana CETP. In 1992, before CETP was instituted, 5 of the 1,500 mathematics and science teachers in the state of Montana were Native American. By the end of the project in 1999, 11 American Indians had graduated certified to teach mathematics or science, and 77 more were in the pipeline, attending tribal colleges or university campuses for secondary mathematics or science certification.

catalyze efforts to improve teacher preparation. See sidebar, "Meeting the Challenge of Teacher Preparation." Alternative certification programs to increase the nation's supply of math and science teachers are aimed at those already in S&E careers or S&E majors who would like to enter K–12 teaching (Feistritzer and Chester 2000; Urban Institute 2000). See sidebar, "Alternative Certification for K–12 Teachers."

National data are scarce with regard to how students go through higher education, the extent of participation, and learning outcomes. See sidebar, "Special New Programs," for information about some funding programs and institutions attempting to implement recommended reforms. Changes include focusing on learning outcomes in undergraduate education, increasing diversity of the S&E workforce, incorporating recent advances in teaching and learning into the undergraduate classroom, and augmenting research experiences for undergraduates.

Graduate S&E Students and Degrees in the United States

Overall Trends in Graduate Enrollment

Is the United States educating an adequate number of bachelor-level S&E majors who are willing and able to pursue advanced degrees in S&E? Has access to graduate programs improved for women and underrepresented minorities? This section presents trends in graduate enrollment: strong growth in foreign student enrollment until 1992 and declining enrollment for both U.S. and foreign citizens from 1993 to 1998. Enrollment of foreign students turned up considerably in 1999, increasing their proportion of the graduate population.

The long-term trend of increasing enrollment in graduate S&E programs in the United States persisted for several decades, peaked in 1993, declined for five years, and then increased in 1999. Trends differ somewhat across S&E fields. For example, enrollment in mathematics and computer sciences peaked in 1992, declined for three years, and then increased from 1995 onward. In contrast, the number of graduate students in engineering declined for six consecutive years (1993–98) before increasing slightly in 1999. (See appendix

Alternative Certification for K–12 Teachers

The use of alternative routes to teaching certification is controversial. Although some experts point out the benefits of more traditional programs such as the use of fifth-year certification programs as a route to alternative certification, they also question the value of short-term alternative certification programs. According to a report from the National Commission on Teaching and America's Future, evaluations of truncated alternative certification programs reveal that students of these teachers learn less than those taught by traditionally prepared teachers (Darling-Hammond 2000). In addition, the report shows that approximately 60 percent of individuals who enter teaching through such programs leave the profession by their third year compared with approximately 30 percent of traditionally trained teachers and only about 10–15 percent of teachers prepared in extended, five-year teacher education programs.

A contrasting view is that alternative routes attract a significantly higher proportion of minority candidates who are more willing to teach mathematics and science in urban and rural environments. Two examples are Troops-to-Teachers and Teach for America. Troops-to-Teachers enables military retirees to prepare to be teachers through existing teacher preparation programs (approximately 50 percent have entered through an alternative teacher preparation and certification program and 50 percent through traditional college-based programs). Since 1994, this program has brought 3,000 military retirees into the teaching profession. According to a recent survey conducted by the National Center for Education Information, Troops-to-Teachers graduates are more likely than the general teaching population to teach mathematics or science (respectively, 29 versus 13 percent teach mathematics and 16 versus 8 percent teach science), be members of minority groups (30 versus 10 percent), or teach in inner-city schools (24 versus 16 percent) (Troops-to-Teachers 2001).

Teach for America enlists liberal arts graduates directly out of college to teach in poor urban and rural schools for at least two years after a summer training period and an induction period at the beginning of the teaching experience. The program has recruited and placed more than 6,000 individuals in teaching positions; 58 percent of the alumni are still in education, of whom 40 percent are full-time teachers. In 1997, 17 percent of matriculants were mathematics and science majors, and 33 percent were African American or Hispanic (Teach for America 2001).

table 2-19.) The favorable job market in the nation after 1992 may account for some of the decline in graduate enrollment. For general workforce conditions that may influence enrollment in higher education, see chapter 3, "Science and Engineering Workforce." The increase in 1999 is mainly accounted for by the increased percentage of foreign students enrolling in U.S. graduate S&E programs. (See appendix table 2-20.)

Graduate Enrollment by Sex, Race/Ethnicity, and Citizenship

The long-term trend of women's increasing proportion of enrollment in all graduate S&E fields has continued during the past two decades, with significant differences by field. By 1999, women constituted 59 percent of the graduate enrollment in social and behavioral sciences and 43 percent of the graduate enrollment in natural sciences. In the same year, women constituted 37 percent of the graduate students in mathematics, 30 percent of the graduate students in computer sciences, and only 20 percent of the graduate enrollment in engineering. However, men are not as prevalent among underrepresented minority groups in NS&E fields; women in underrepresented minority groups have a higher proportion of graduate enrollment than women in other groups. For example, one-third of black graduate students in engineering and more than one-half of the black graduate students in natural sciences are women. (See text table 2-10.)

Graduate enrollment trends also differ by race and ethnicity. The proportion of total enrollment represented by white (majority) students in graduate S&E programs declined from 65 percent in 1975 to less than 53 percent in 1999. In contrast, the number of underrepresented minority students in graduate S&E programs has increased during the past two decades. However, the rate of increase has slowed from 6.5 percent in the 1986–92 period to 4.1 percent in the 1992–99 period. Underrepresented minorities, which make up almost 25 percent of the U.S. population, represent 9.3 percent of the students in graduate S&E programs in U.S. higher education. Asians/Pacific Islanders are well represented in advanced S&E education, constituting 4 percent of the U.S. population and 6.7 percent of the graduate students in S&E programs. (See appendix table 2-20.)

After a four-year decline (1993–96), the number of foreign students enrolling in U.S. graduate S&E programs turned around in 1997 and 1998 and increased sharply in 1999. The decline in foreign students from 1993 to 1996 (and the subsequent decline in foreign doctoral degree recipients in 1997–99) is partly explained by fewer Chinese students coming to the United States during the few years after Tiananmen Square and the Chinese Student Protection Act. Chinese student enrollment in the U.S. S&E graduate programs declined from 28,823 in 1993 to 24,871 in 1995 and then continued to increase in subsequent years. However, the number of graduate S&E students from India, South

Special New Programs

Some programs and institutions of higher education have supported recommended reforms.

Focusing on Learning Outcomes

Newly adopted accreditation guidelines for both the Accreditation Board of Engineering and Technology (2001) and the National Council for Accreditation of Teacher Education are based on outcome rather than simply on courses of study and admission criteria (Wise 2001).

Recent surveys of higher education institutions have included specific questions related to employer and general public satisfaction and student perception of their experience in terms of the number and quality of their contact with faculty, level of academic challenge, internships and study abroad projects, frequency of student group and community projects, signs of active and collaborative learning, and other factors (NGA Center for Best Practices 2001; PEW Forum on Undergraduate Learning 2000).

Increasing the Diversity of the S&E Workforce

The production of minority science and engineering bachelor's degrees from the first set of institutions involved in an NSF program aimed at increasing minority S&E students has increased from 3,900 in 1990 to 7,200 in 2000 (Dale 2001).

Incorporating Recent Advances in Teaching and Learning Into the Undergraduate Classroom

Many institutions are experimenting with creating learning communities to encourage S&E students to understand the basic concepts of the phenomena they are studying and to help each other learn. For example, on a single-course basis, a consortium of nearly 60 institutions has added student-led discussion workshops to their organic chemistry classes. Students meet in workshops, are handed observations from a specific chemical technique (e.g., infrared spectroscopy), and are asked to jointly analyze the results. They work in teams and are encouraged to engage everyone on the team in devising solutions. At one participating institution, the University of Rochester, where only 67 percent of organic chemistry students in the early 1990s earned the "C" necessary to enroll in more advanced chemistry courses, 79–82 percent of the students now earn a "C" or better. These results are mirrored throughout the consortium (Cox 2001).

One effort involving a related series of courses is aimed at increasing the retention of entering prescience and preengineering students at the University of Texas at El Paso. Students are assigned to a block of three linked courses (an English course, a mathematics course, and a seminar course with a science or engineering theme) featuring cooperative learning techniques. Twelve percent more of the students in the cluster groups remained S&E majors (80 percent retained) compared with nonclustered students (68 percent retained) (Rothman and Narum 1999).

In response to the findings of research on learning and teaching, numerous efforts have been initiated to more actively involve students in classes. Examples range from course-specific efforts such as those of Eric Mazur, a physics professor at Harvard, to more universal approaches such as the adoption of problem-based learning techniques in all basic science courses at the University of Delaware. As much as one-third of Mazur's physics classroom time is devoted to consideration of conceptual questions related to the subject of the day. Mazur poses a challenging question to the class, students record their answers via computer, and the results are discussed, resulting in increased student interest and participation and an opportunity for the faculty to correct misconceptions as they occur. The University of Delaware finds that problem-based learning promotes active learning and connects concepts to applications. A real-life science-related problem is presented to students, who then work in groups to gather information from appropriate sources and develop a reasonable solution (The Boyer Commission on Educating Undergraduates 1998).

Augmenting Research Experiences for Undergraduates

Numerous universities are incorporating research experiences for either a distinct subset or all of their S&E majors. Summer opportunities for research included approximately 400 NSF Research Experiences for Undergraduates projects in the nation in 2000, serving about 4,000 undergraduates (NSF/EHR 2001b); research opportunities for students preparing to be teachers initiated as a joint project of the Department of Energy and the National Science Foundation (NSF/EHR 2001c); and programs supported by the Howard Hughes Medical Institute (2001).

To encourage a research-based approach to education in S&E, Rensselaer Polytechnic Institute has redesigned its large introductory courses, replacing lecture, recitation, and laboratory with a studio format taught in a specially designed facility by a single faculty member assisted by one graduate student and several undergraduates (The Boyer Commission on Educating Undergraduates 1998).

The University of Arizona is attempting to make research opportunities an integral part of each student's undergraduate experience through the introductory biology course, serving about 1,800 students per year. In addition, two undergraduate laboratory research experiences are offered, one in faculty laboratories at the University of Arizona and a followup experience in biomedical research abroad.

Text table 2-10.
Female enrollment in U.S. graduate S&E programs among racial/ethnic groups and foreign students, by discipline: 1999
(Percentages)

Race/ethnicity and citizenship	Total S&E	Natural sciences	Mathematics	Computer sciences	Social and behavioral sciences	Engineering
Total	41	43	37	30	59	20
White	44	44	37	25	60	19
Asian/Pacific Islander	42	49	44	38	63	25
Black	58	58	45	45	66	33
Hispanic	50	50	39	24	63	24
American Indian/Alaskan Native	52	49	60	32	62	28
Foreign students	30	37	35	30	45	18

NOTES: Foreign students include those on temporary visas only. Values are percentages of total enrollment for each subgroup within each field. Natural sciences include physics, chemistry, astronomy, and biological, agricultural, earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Science Resources Studies (NSF/SRS), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1999,* NSF 01-315 (Arlington, VA, 2001).

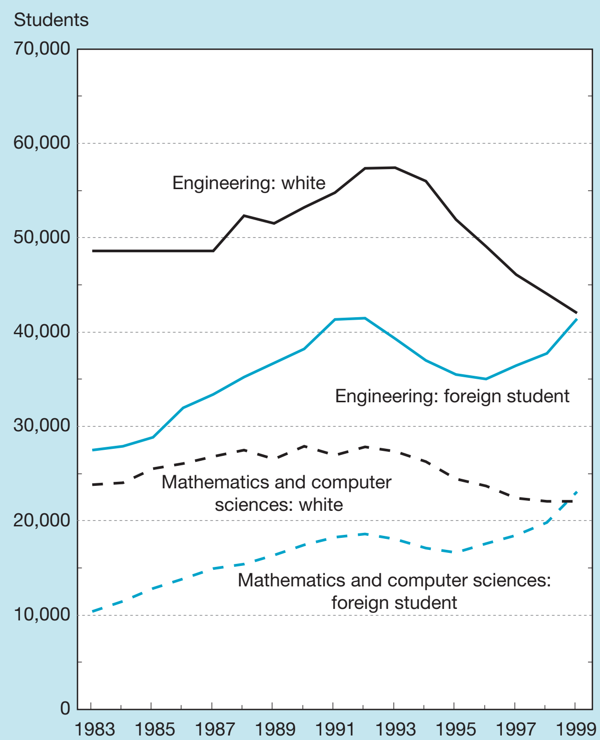
Science & Engineering Indicators – 2002

Korea, Taiwan, Indonesia, and Malaysia also declined in various years in the 1990s because of expanded opportunities for graduate education within their own countries or regional economies. (See appendix table 2-21.)

Despite the four-year decline, the longer term trend shows increasing enrollment of foreign graduate students in S&E fields in U.S. institutions. Evidence shows that foreign student enrollment also is increasing in other major host countries (the United Kingdom and France) and to other host countries (Germany and Japan). See "International Comparison of Foreign Student Enrollment in S&E Programs." The international trend may be driven by the desire for advanced training in S&E fields and employment opportunities in S&E careers. In 1999, this increasing foreign enrollment, coupled with a declining number of U.S. white (majority) students, resulted in an approximately equal number of white and foreign students in the U.S. graduate programs in mathematics, computer sciences, and engineering. (See figure 2-13.)

The NSF 1999 Survey of Graduate Students and Postdoctorates in Science and Engineering (NSF/SRS 2001a) shows that more than 100,000 foreign students were enrolled in U.S. S&E graduate programs. They represent a significant proportion of engineering (41 percent) and math and computer science (39 percent) students. Except for Canada, the 10 top countries of origin of foreign students to the United States are in the Asian region. Trends in enrollment from particular Asian countries and economies show a decline through most of the 1990s for students from Taiwan, a leveling off of students from South Korea, and an increasing number of students from China and India after a temporary drop. (See figure 2-14, appendix table 2-21, and "International Comparisons of Foreign Student Enrollment in S&E Programs" at the end of the chapter.)

Figure 2-13.
Trends in graduate enrollment in mathematics and computer sciences and in engineering: 1983–99



NOTE: White includes U.S. citizens and permanent residents; foreign student includes temporary residents only.

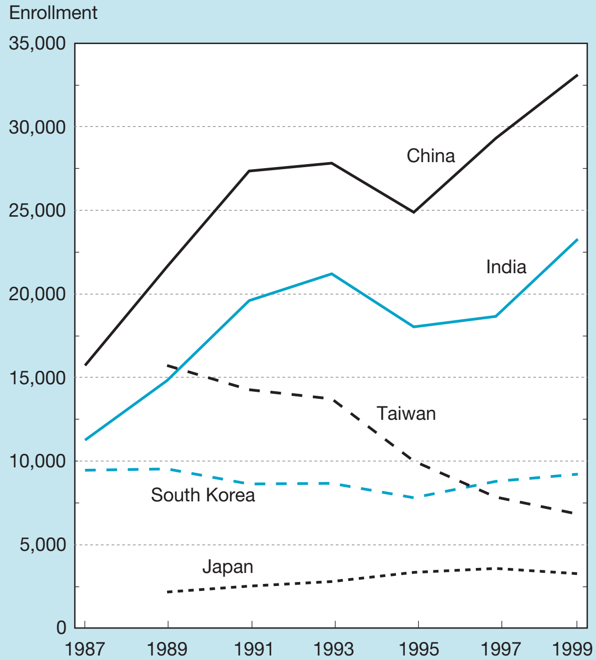
See appendix table 2-20. *Science & Engineering Indicators – 2002*

Master's Degrees

Overall Trends

Declining S&E degree trends at the master's level resemble those at the bachelor's level. The number of degrees earned in engineering, the most attractive major at the master's level, increased rapidly for more than a decade, peaked in 1994, declined for three consecutive years, and leveled off. The number of degrees earned in social sciences, psychology, and biological/agricultural sciences increased strongly in the 1990s

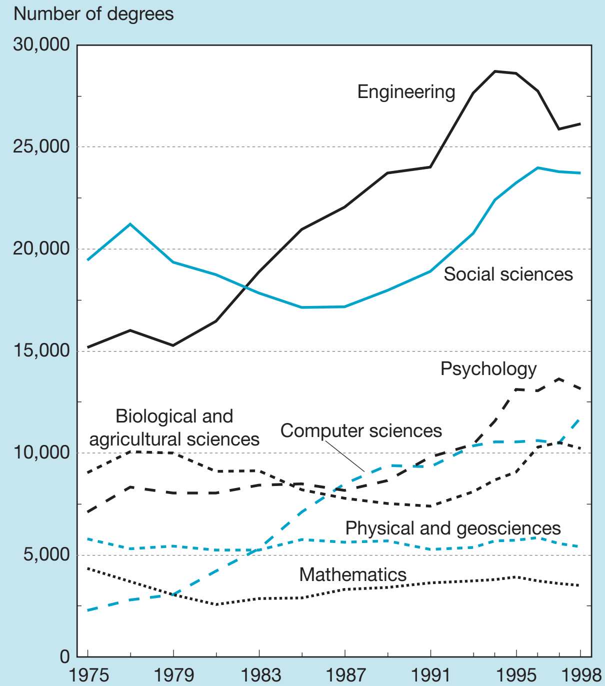
Figure 2-14.
Foreign student enrollment in U.S. S&E graduate programs, by selected countries and economies: 1987–99



NOTES: Data for 1999 are estimated based on the previous percentages of graduate students from each country who enrolled in S&E fields. Foreign students include only those on temporary visas.

See appendix table 2-21. *Science & Engineering Indicators – 2002*

Figure 2-15.
Master's degrees awarded in S&E, by field: 1975–98



NOTE: Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-22. *Science & Engineering Indicators – 2002*

and leveled off in the past few years. The corresponding statistics for mathematics, physical sciences, and geosciences have remained stable during the past few decades. The number of degrees earned in computer sciences remained essentially flat for most of the 1990s; computer sciences is one of the few S&E fields that exhibited an increase in degrees earned in 1998. (See figure 2-15.)

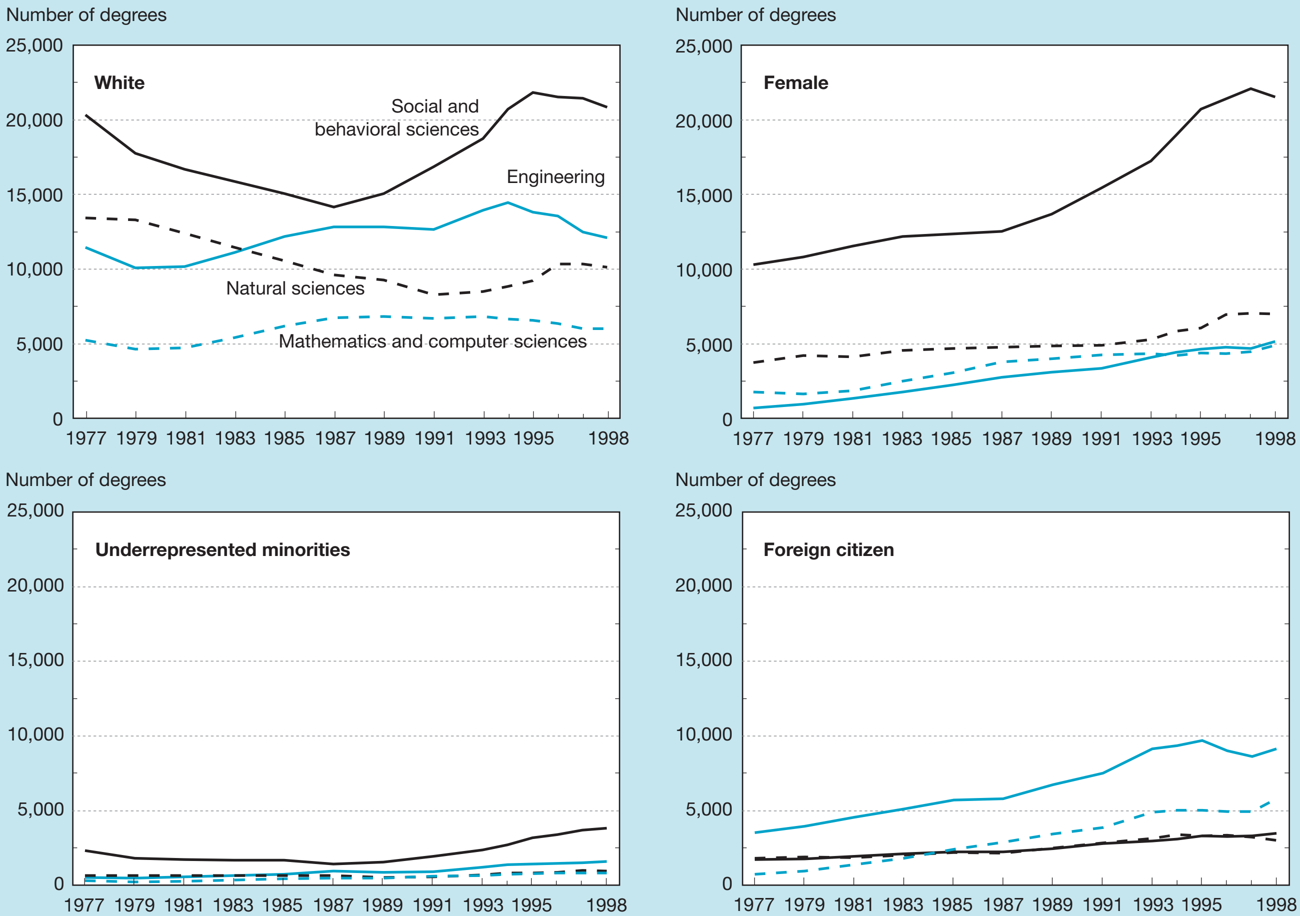
Master's Degrees by Sex, Race/Ethnicity, and Citizenship

Trends for men earning master's degrees differ slightly from trends for women. For men, growth in the number of degrees earned in biological and social sciences and psychology was more modest, and growth in computer sciences was stronger until 1996, when the number of degrees earned declined. Trends for women show continuously strong increases during the past two decades in biological and social sciences and psychology, modest increases in computer and physical sciences, and constant levels in mathematics, with a slight downturn in mathematics and physical sciences after 1996. (See appendix table 2-22.)

Trends also differ by race/ethnicity and citizenship. White students follow the overall trends, with increases in biological and social science, psychology, and computer science degrees earned in the 1980s, followed by steady decreases throughout the 1990s. In contrast, trends for Asian/Pacific Islander students show an increasing number of degrees earned in all S&E fields, particularly in computer sciences. S&E trends for blacks at the master's level show strong growth in the number of degrees earned in social sciences and psychology and modest growth in biological and computer sciences. Hispanic students also show strong growth in the number of degrees earned in social sciences and psychology, modest growth in biological sciences, and minor fluctuations in computer sciences. American Indians/Alaskan Natives earned an increasing number of degrees in social sciences and psychology, but the number of degrees earned in all other fields fluctuated around a low base. The number of degrees earned by foreign students increased in all S&E fields, particularly computer sciences, until 1993 and then leveled off or declined. Trends in broad fields are shown for selected groups in figure 2-16.

Among the new directions in graduate education are the creation of the new "terminal" master's degrees and the proliferation of professional certificate programs. Terminal master's programs provide the skills (often interdisciplinary) needed by professionals working in emerging S&E fields. Professional certificates that are approved by graduate programs include a coherent set of courses for a specialty, such as engineering management. The latter are amenable to distance delivery at corporate sites. See sidebar, "Terminal Master's Degree Programs."

Figure 2-16.
Master's degrees in S&E fields earned by selected groups: 1977–98



Underrepresented minorities = black, Hispanic, and American Indian/Alaskan Native

NOTES: Data are estimated for 1983. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. White and underrepresented minorities include U.S. citizens and permanent residents. Foreign citizen includes temporary residents.

See appendix tables 2-22 and 2-23. *Science & Engineering Indicators – 2002*

Doctoral Degrees

Overall Doctoral Trends

After a steady upward trend during the past two decades, the overall number of doctoral degrees earned in S&E fields declined in 1999. Trends differ by field. Degrees in biological sciences followed the overall pattern and declined for the first time in 1999. The number of degrees earned in engineering peaked in 1996 and declined for the next three years. This decrease in the number of engineering degrees earned is accounted for mainly by the decrease in the number of degrees earned by foreign students from 1996 to 1999. See "Doctoral Degrees by Citizenship." The number of degrees earned in psychology and social sciences increased slightly in the 1990s and leveled off in 1998–99. The number of degrees earned in the physical sciences and geosciences, mathematics, and computer sciences was stable in the 1990s and declined slightly in 1999. (See figure 2-17.)

Doctoral Degrees by Sex

At the doctoral level, the proportion of S&E doctoral degrees earned by women has risen considerably in the past three decades, reaching a record 43 percent in 1999. (See figure 2-18.) However, dramatic differences by field exist. In 1999, women earned 23 percent of the doctoral degrees awarded in physical sciences, 18 percent of those in computer sciences, and 15 percent of those in engineering. However, they earned more than 41 percent of the degrees awarded in biological and agricultural sciences and 42 percent of those awarded in social sciences. Women earned most of the degrees (66 percent) awarded in psychology.[4] (See appendix table 2-24.) The long-term trend of an increasing number of doctoral degrees earned by women halted in 1999, with slight decreases in biological and physical sciences and a leveling off in other S&E fields (NSF/SRS 2001d). (See appendix table 2-24.)

[4]See National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1999*, table 2, for percentages of doctoral degrees earned by women for detailed S&E fields in 1990 and 1999.

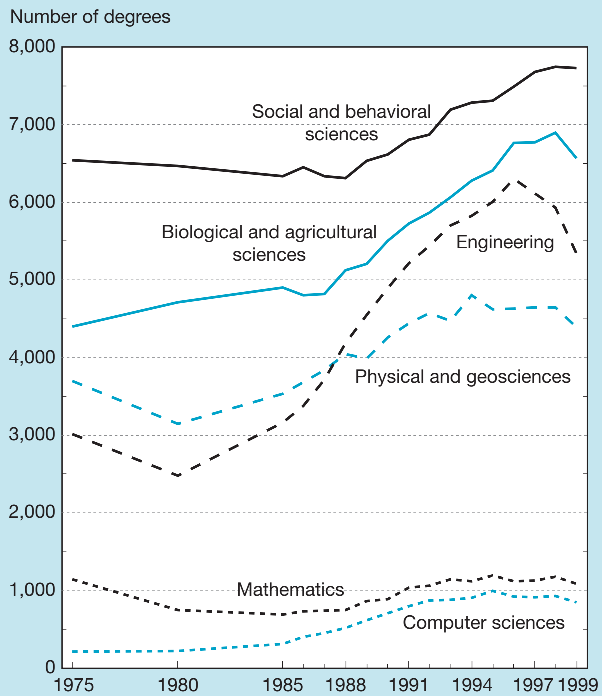
Terminal Master's Degree Programs

Terminal master's degree programs might be viewed as the science equivalents of master's degree programs in business administration (Littman and Ferruccio 2000). Although these programs have existed for many years, industrial and academic interest is growing in programs that prepare students to enter emerging science and engineering (S&E) fields (e.g., bioinformatics and computational chemistry) as skilled professionals. These programs tend to be broader than just one field and require skills in various disciplines.

The Sloan and Keck Foundations are supporting development of such programs to supply the growing S&E technical needs of industry, government agencies, and academic researchers and to answer the needs of students who do not want to go into clinical medicine or research careers but want to remain in science or mathematics (Tobias 2000). National data concerning how many of these programs exist or how many students participate in them will not emerge for several years. In 2000, the Sloan Foundation supported 17 such programs distributed among five universities, and at least 7 more programs distributed among three new university participants are planned for 2001.*

*For more information, see <http://www.sciencemasters.com>.

Figure 2-17.
Doctoral S&E degrees earned in U.S. universities, by field: 1975–99



NOTES: Data are in five-year increments for 1975–85, and one-year increments for 1985–99. Geosciences include earth, atmospheric, and ocean sciences.

See appendix table 2-24. *Science & Engineering Indicators – 2002*

Doctoral Degrees by Race/Ethnicity

In the past decade, the white (majority) population earned a slightly increasing number of doctoral degrees across most S&E fields, followed by a downturn in most fields in 1998–99. In the same period, underrepresented minorities also earned an increasing number of doctoral degrees across all fields, mainly in social, behavioral, and natural sciences. Their increases were from such a low base, however, that the number of doctoral degrees awarded to underrepresented minorities is barely visible on a graph that compares S&E degrees earned by various groups. (See figure 2-19.) The modest gains in the number of degrees earned in engineering, mathematics, and computer sciences continued in the 1990s until 1998, when the number of degrees earned in these fields turned slightly downward. Among Asians/Pacific Islanders who were citizens and permanent residents, the steep increases in the mid-1990s mainly reflect the Chinese foreign students on temporary visas shifting to permanent resident status from the 1992 Chinese Student Protection Act. The number of degrees earned by Asians/Pacific Islanders has since leveled off. (See appendix table 2-25.)

Doctoral Degrees by Citizenship

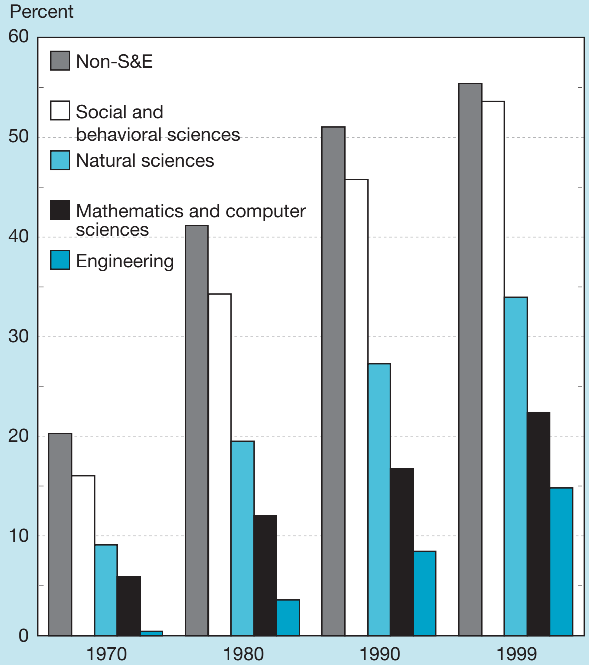
Each year from 1986 to 1996, the number of foreign students earning S&E doctoral degrees at universities in the United States increased; after that, this number of earned degrees dropped off. The number of such degrees earned by foreign students increased much faster (7.8 percent annually) than the number earned by U.S. citizens (2 percent annually). (See appendix table 2-26.) For example, the number of foreign students earning doctoral degrees in S&E increased from 5,000 in 1986 to almost 11,000 in the peak year of 1996, with declines each succeeding year.[5] During the 1986–99 period, foreign students earned 120,000 doctoral degrees in S&E fields. China is the top country of origin of these foreign students; almost 24,000 Chinese students earned S&E doctoral degrees at universities in the United States during this period (NSF/SRS 2001d).

The decline in S&E doctoral degrees earned by foreign students mirrors their declining enrollment in graduate S&E programs from 1993 through 1996. (See appendix table 2-20.) After this four-year drop-off in enrollment, the number of foreign graduate students stabilized in 1997 and increased in 1998 and 1999. (The number of foreign doctoral recipients may increase within the next few years if their graduate enrollment in U.S. institutions continues to increase.)

Foreign students earn a larger proportion of degrees at the doctoral level than any other degree level, more than one-third of all S&E doctoral degrees awarded. (See figure 2-20.)

[5]Numbers include students on both temporary and permanent visas but not naturalized citizens.

Figure 2-18.
Doctoral degrees earned by women in U.S. institutions, by field: 1970–99



NOTE: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix table 2-24. *Science & Engineering Indicators – 2002*

Their proportion in some fields is considerably higher: in 1999, foreign students earned 47 percent of doctoral degrees awarded in mathematics and computer sciences and 49 percent of those awarded in engineering.

Doctoral Reform

The need for reform of doctoral education has been widely noted and discussed. In 1995, the Committee on Science, Engineering, and Public Policy (COSEPUP) recommended broadening the education of doctoral students beyond research training. Because more than one-half of all doctoral recipients obtain nonacademic employment, COSEPUP recommended that doctoral students acquire an education in the broad fundamentals of their field, familiarity with several subfields, the ability to communicate complex ideas to nonspecialists, and the ability to work well in teams (COSEPUP 1995). Subsequently, professional societies and leading educators encouraged the expansion of COSEPUP recommendations beyond physical sciences and engineering to include all graduate education.

NSF responded to COSEPUP's recommendations by funding universities to establish Integrative Graduate Education and Research Traineeship (IGERT) programs. Such awards enable universities to offer stipend support to graduate students to engage in research in emerging multidisciplinary areas of S&E (NSF/EHR 2001a). From 1997 to 2000, NSF granted university faculties a total of 57 awards in the IGERT program.

Current research on doctoral education shows that doctoral students' high level of interest and belief in the possibility of a faculty career persist even though the number of doctoral degrees granted far exceeds available tenure-track positions. See sidebar, "At Cross Purposes."

Current efforts focus on how to "re-envision the Ph.D." to meet the needs of society in the 21st century and how to effect reforms without lengthening the time to achieve a degree. The re-envisioning project provides a forum for national dialog on doctoral reforms among key stakeholders: research- and teaching-intensive institutions, doctoral students, agencies that fund and hire doctoral recipients, disciplinary societies, and education associations. A recent workshop composed of many such stakeholders agreed on six themes for doctoral reforms:

- shorten time to degree acquisition,
- increase underrepresented minorities among doctoral recipients,
- improve the use of technology for research and instructional purposes,
- prepare students for a wider variety of professional opportunities,
- incorporate understanding of the global economy and international scientific enterprise, and
- provide doctoral students with an interdisciplinary education.

The project also collects and disseminates promising practices for doctoral education that are submitted by individual departments (Nyquist and Woodford 2000). See also chapter 3 on "Science and Engineering Workforce" for employment prospects of doctoral recipients by field and the sidebar, "International Efforts in Doctoral Reform," at the end of this chapter.

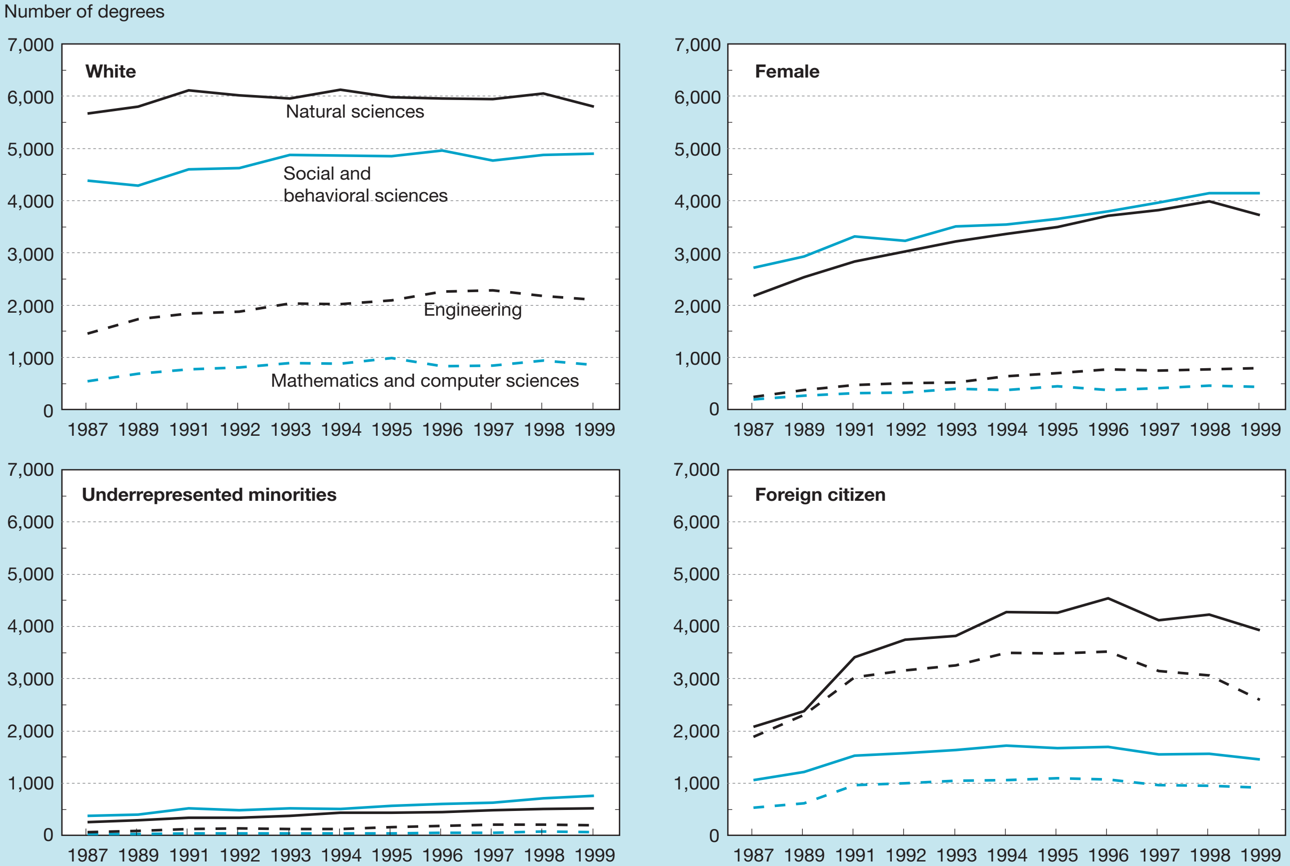
Financial Support for S&E Graduate Education

U.S. higher education in S&E fields has traditionally coupled advanced education with research. This coupling is reflected by the various forms of financial support for S&E graduate students, particularly those pursuing doctoral degrees. Support mechanisms include fellowships, traineeships, research assistantships (RAs), and teaching assistantships (TAs).

Sources of support include Federal agency support, non-Federal support, and self-support. See sidebar, "Definitions and Terminology," for fuller descriptions of both mechanisms and sources of support. Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source and one mechanism during their time in graduate school; some graduate students may even receive support from several different sources and mechanisms in any given academic year.

This section describes both sources and mechanisms of financial support. During the 1990s, the distribution of different mechanisms of support stabilized after the importance of RAs increased during the 1980s. The increase was offset

Figure 2-19.
Doctoral degrees in S&E fields earned by selected groups



NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences. Underrepresented minorities include black, Hispanic, and American Indian/Alaskan Native. White and under-represented minorities include U.S. citizens and permanent residents. Foreign citizen includes those on either permanent or temporary visas.

See appendix tables 2-24, 2-25, and 2-26. *Science & Engineering Indicators – 2002*

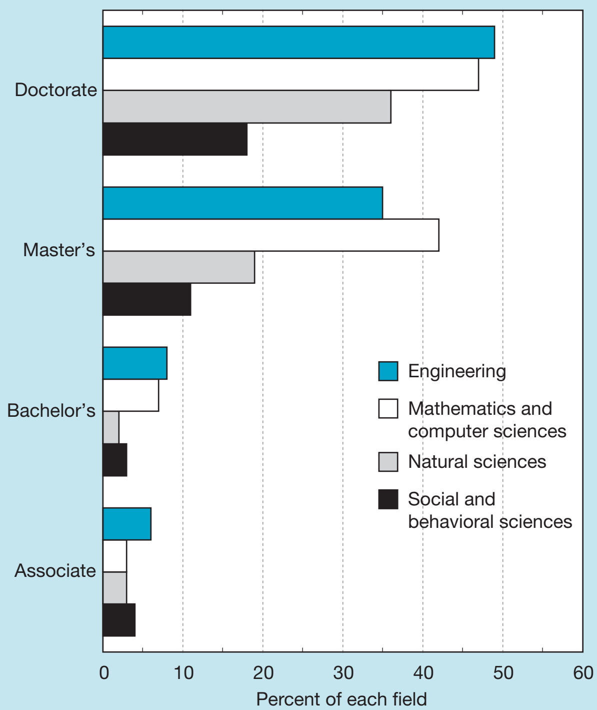
by a reliance on traineeships and self-support. The relative stability in the proportion of different mechanisms of support in the 1990s holds for both federally and nonfederally supported students. Federal support is found predominantly in the form of RAs, which represent 66 percent of all Federal support. However, Federal support through fellowships increased slightly in the 1990s, from 9 percent in 1989 to 11 percent in 1999. For students supported through non-Federal sources, TAs are the most prominent mechanism (41 percent), followed by RAs (30 percent). (See appendix table 2-27.)

Primary mechanisms of support differ widely by S&E fields of study. For example, students in physical sciences are supported mainly through RAs (42 percent) and TAs (41 percent). RAs also are important in engineering (42 percent) and earth, atmospheric, and ocean sciences (41 percent). In mathematics, however, primary student support is through TAs (57 percent) and self-support (17 percent). Students in social sciences are mainly self-supporting (41 percent) or receive TAs (22 percent). (See appendix table 2-28.)

The Federal Government plays a significant role in supporting S&E graduate students in some selected fields and mechanisms and an insignificant role in others. For example, Federal traineeships represent approximately two-thirds of all such support, almost one-half of all RAs, and one-quarter of all fellowships. The percentage of Federal traineeships is even greater in physical and biological sciences and in chemical engineering, and the Federal Government supports most RAs in physical sciences. In contrast, the Federal Government is not a significant source of support for graduate education in social sciences, psychology, and mathematics. (See appendix table 2-29.)

The National Institutes of Health (NIH) and NSF support most of the S&E graduate students whose primary support comes from the Federal Government, 17,000 and 14,000 students, respectively. Trends in Federal agency support of graduate students show a considerable increase in the proportion of students supported primarily by NIH, from less than 22 percent in 1980 to 29 percent in 1999. The proportion of graduate students receiving Federal support primarily by NSF has

Figure 2-20.
S&E degrees earned by foreign students within each field, by level: 1998–99



NOTES: Doctoral degree data are for 1999; all others are 1998 data. At the doctoral level, foreign students include both permanent and temporary residents; all other levels include only temporary residents. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix tables 2-15, 2-17, 2-23, and 2-26.

Science & Engineering Indicators – 2002

At Cross Purposes

A recent survey of doctoral programs queried students in three areas: their goals, the effectiveness of doctoral programs in preparing students for careers within and outside academia, and the level of student satisfaction with their programs (Golde and Dore 2001).

The findings revealed that most students interviewed were interested in a faculty job in the future. When questioned about preparation for various aspects of their future career, 65 percent of the students indicated that they were prepared by their program to conduct research; fewer felt prepared to publish their research findings (43 percent) or collaborate in interdisciplinary research (27 percent). Relatively few students (38 percent) reported that they were encouraged to take part in nonacademic job search workshops.

More than half of all doctoral students had opportunities to improve their teaching skills, but these opportunities varied greatly among the disciplines surveyed. Training courses for teaching assistants were least likely in chemistry (28 percent) and molecular biology (30 percent).

Overall, students reported being satisfied with their decision to pursue doctoral degrees; however, they were less certain about the details of pursuing a doctoral education in regard to their daily lives. They entered the program without having a good idea of the time, money, clarity of purpose, and perseverance that doctoral study requires. Once enrolled, they received little guidance on how to complete the process successfully.

increased from 18 to 21 percent in the past two decades. In contrast, the Department of Defense provided primary support for a declining proportion of students funded primarily by Federal sources: 17 percent in 1988 and 12 percent in 1999. (See appendix table 2-30.)

Support Mechanisms for Doctoral Students

For doctoral students, support mechanisms can be classified by sex, race/ethnicity, and citizenship. For men, the leading support mechanism is RAs, followed by personal sources. For women, the leading support mechanism is personal sources, followed by fellowships. Foreign doctoral students serve as S&E research and teaching assistants and are more likely to have RAs and TAs as their primary sources of support. For example, more than 80 percent of the Chinese doctoral degree recipients in the United States from 1988 to 1996 reported in the U.S. Survey of Earned Doctorates (SED) that they were supported by university RAs,[6] and more than 50 percent reported financial support from TAs (NSF/SRS 2001a). U.S. citizens are more likely to have personal sources of support. For underrepresented minorities, however, fellowships are the primary source of support. (See appendix table 2-31.)

Stay Rates of Foreign Doctoral Recipients

Historically, approximately 50 percent of foreign students who earned S&E degrees at universities in the United States reported that they planned to stay in the United States, and a smaller proportion had firm offers to do so (NSF/SRS 1998). In 1990, for example, 45 percent of all foreign S&E doctoral degree recipients planned to remain in the United States after completing their degree, and 32 percent had received firm offers. As a result of the strong economy and employment opportunities of the 1990s, however, these percentages increased significantly. By 1999, more than 72 percent of foreign doctoral recipients in S&E fields planned to stay in the United States, and 50 percent accepted firm offers to do so. (See figure 2-21 and appendix table 2-32.)

The number of S&E doctoral degrees earned by foreign students declined after 1996, but the number of students who had firm plans to remain in the United States declined only slightly from its 1996 peak. Each year from 1996 to 1999,

[6] Much of the funding for university RAs is derived from Federal grants to universities.

Definitions and Terminology

Fellowships are competitive awards (often from a national competition) given to students for financial support of their graduate studies.

Traineeships are educational awards given to students selected by the institution.

Research assistantships are given to students whose assigned duties are devoted primarily to research.

Teaching assistantships are given to students whose assigned duties are devoted primarily to teaching.

Other mechanisms of support include work-study programs, business or employer support, and support from foreign governments that is not in the form of a previously mentioned mechanism.

Self-support is derived from any loans obtained (including Federal loans) or from personal or family contributions.

Federal support comes from Federal agencies; examples are the GI bill and tuition paid by the Department of Defense for members of the Armed Forces.

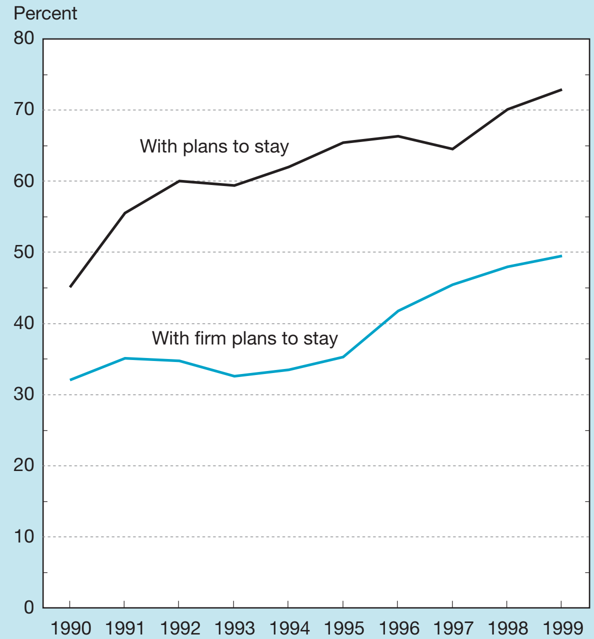
Non-Federal support comes from the student's institution of higher education, state and local government, foreign sources, nonprofit institutions, or private industry.

more than 4,000 foreign doctoral recipients had firm offers to remain in the United States at the time of degree conferral. (See figure 2-22.) These firm offers were mainly for post-doctorate appointments and industrial employment in research and development (R&D).

Foreign doctoral students' plans to stay in the United States differ by region of origin. Those from East and South Asia receive the highest number of doctoral degrees by far and constitute the highest percentage of students who plan to stay in the United States. (See text table 2-11.) Countries within regions also differ significantly. In Asia, China and India have higher-than-average firm stay rates in the United States, and South Korea and Taiwan have lower-than-average firm stay rates. In North America, Mexico has a far lower stay rate than Canada. The United Kingdom has the highest stay rate among European countries; in 1999, 79 percent planned to stay in the United States after earning their doctorate in S&E fields, and 62 percent had firm offers to do so. (See figure 2-23.)

After 1996, the number of foreign doctoral degree recipients from China, Taiwan, and India with plans to stay in the United States declined slightly, even though the proportion that planned to stay increased. Because the number of S&E doctoral degrees earned by these groups decreased after 1996, the net result was that fewer remained in the United States. (See figure 2-24.)

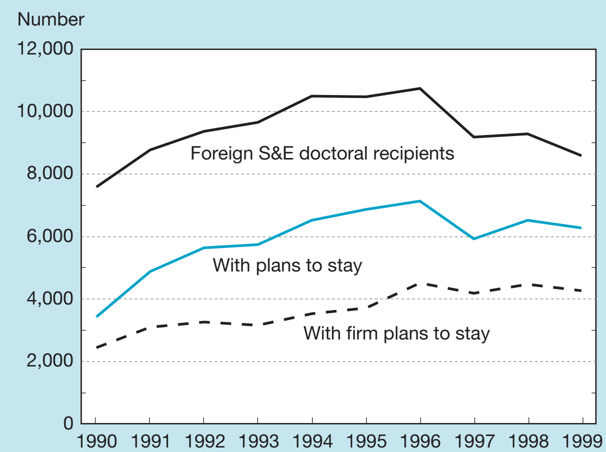
Figure 2-21.
Percentage of foreign S&E doctoral recipients with plans to stay in United States: 1990–99



NOTE: Data include foreign doctoral recipients with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

Figure 2-22.
Foreign S&E doctoral recipients with plans to stay in United States: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

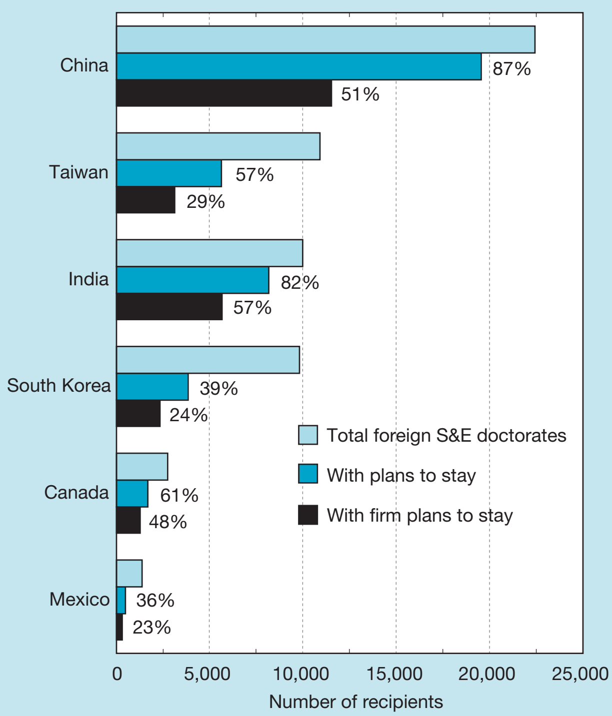
The SED data on stay rates can be used to indicate immediate reverse flow of foreign doctoral recipients. Those with no plans to stay in the United States may be planning an immediate return to their home country or to another country in the region. For example, Chinese doctoral recipients with no plans to stay in the United States may be hired by a research

Text table 2-11.
Foreign S&E doctoral recipients with plans to stay in the United States, by region: 1990–99

		With plans to stay		With firm plans to stay	
Region	Total	Number	Percent	Number	Percent
All regions	93,682	58,553	62.5	36,327	38.8
East/South Asia	57,609	39,154	68.0	23,932	41.5
West Asia	8,757	4,676	53.4	2,548	29.1
Pacifica/Australia	2,075	986	47.5	627	30.2
Africa	4,464	2,100	47.0	967	21.7
Europe	11,698	7,260	62.1	5,191	44.4
North/South America	9,079	4,377	48.2	3,062	33.7

See appendix table 2-32 for countries within each region. *Science & Engineering Indicators – 2002*

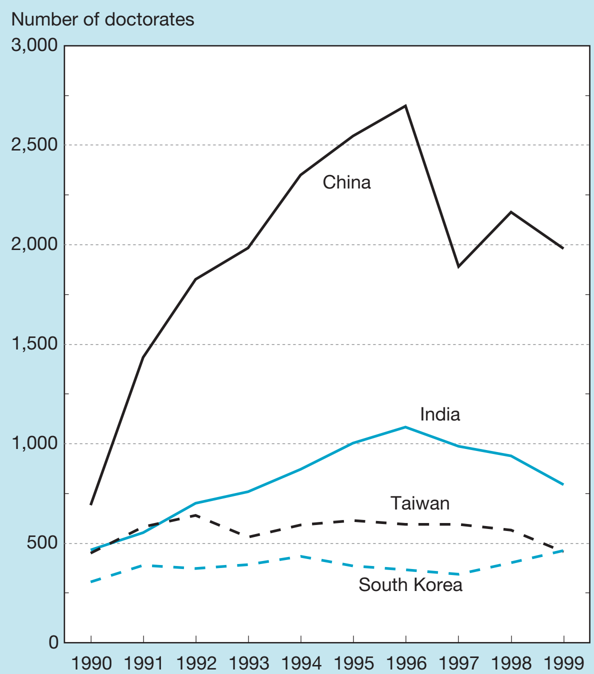
Figure 2-23.
Foreign S&E doctoral recipients with plans to stay in the United States, by place of origin: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

Figure 2-24.
U.S. S&E doctoral recipients from selected Asian countries and economies with plans to stay in the United States: 1990–99



NOTE: Foreign doctoral recipients include those with either permanent or temporary visas.

See appendix table 2-32. *Science & Engineering Indicators – 2002*

institute in China or Singapore. The rate of return of S&E doctoral recipients from universities in the United States differs by country of origin. Mexico and Brazil have the highest reverse flow; India and China have the lowest. (See text table 2-12.)

Recently, the Social Science Research Council surveyed the rates of return of African Ph.D. recipients trained in U.S. and Canadian universities between 1986 and 1996. The survey found that 63 percent of these recipients were employed in their home country or a neighboring African country by 1999.[7] The factors that correlated with returning home were the home country of the degree holder, field of study, and type of funding for

[7] SED shows that 64 percent of African doctoral recipients planned to stay in the United States; however, because many were in biological sciences, they may have stayed for a postdoctorate for a few years and then returned to Africa. SSRC findings are relatively consistent with Finn's research on stay rates several years after Ph.D. attainment (Finn 1999). Finn's work shows that about 44 percent of African doctoral recipients were working in the United States several years after receiving their Ph.D.

Text table 2-12.
Foreign S&E doctoral recipients who returned home, by place of origin, selected countries and economies

Location of origin	Total recipients	Percentage who returned home
United Kingdom (1998)		
China	208	59
Malaysia	145	99
Germany	146	57
Greece	118	64
Iran	127	89
United States	80	75
Turkey	124	100
Canada	59	71
Taiwan	82	95
Ireland	61	45
United States (1999)		
China	2,187	10
India	888	10
South Korea	738	37
Taiwan	732	38
Canada	283	28
Turkey	186	41
Germany	179	35
Mexico	158	69
Brazil	156	69
United Kingdom	141	21

NOTES: U.S. data are foreign students with no plans to stay in the United States. Foreign students include those on either permanent or temporary visas.

SOURCES: Higher Education Statistics Agency, First Destination Survey of 1998 Doctoral Recipients, unpublished tabulations, 2001; and appendix table 2-32. *Science & Engineering Indicators – 2002*

graduate study. Economic opportunities, political stability, and institutional conditions for establishing a professional career correlated with high return rates. The fields of agricultural and biological sciences, which receive high funding priorities in some African countries, also correlated with high return rates (Pires, Kassimir, and Brhane 1999).

Foreign doctoral recipients in S&E who remain in the United States represent a potential "brain drain" from their country of origin, but they also have an opportunity for enhanced research experience before returning home. Reverse flow back home is increasing for countries with increasing S&E employment in higher education and research institutes. Little is known of the broader diffusion of S&E knowledge by foreign doctoral recipients who remain in the United States through activities such as cooperative research, short-term visits, and networking with scientists at home and abroad. See sidebar, "Reverse Flow."

Increasing Global Capacity in S&E

This section places data from the United States in an international context, including comparisons of bachelor's (first university) degrees, participation rates in S&E degrees, doctoral degrees, the level of foreign student enrollment, and the percentage of foreign students earning S&E doctoral degrees in major host countries. Information is provided on reforms to improve the quality of expanded doctoral programs in Europe and Asia and the stay rate and return flow of foreign doctoral recipients in a few other major host countries (the United Kingdom and France).

In regard to doctoral degrees, the proportion of S&E degrees earned outside the United States is shifting, which may eventually translate into a corresponding shift in research capacity, scientific output, and innovative capacity. See chapter 4, "U.S. and International Research and Development: Funds and Alliances," and chapter 5, "Academic Research and Development." The United States needs to devise effective forms of collaboration and information exchange to benefit from, and link to, the expanding scientific capabilities of other countries and regions. For example, increased international coauthorship may indicate that the United States is staying in touch with expanded research abroad. See "Scientific Collaboration" in chapter 5.

International Comparison of First University Degrees in S&E Fields

In 1999, more than 2.6 million students worldwide earned a first university degree in science or engineering.[8] (Note that the worldwide total includes only countries for which recent data are available, primarily the Asian, European, and American regions, and is therefore an underestimation.) Approximately 900,000 degrees were earned in fields within each of the broad categories of natural sciences, social and behavioral sciences, and engineering. (See appendix table 2-18.)

From among reporting countries, more than 1.1 million of the 2.6 million S&E degrees were earned by Asian students at Asian universities. Students across Europe (including Eastern Europe and Russia) earned almost 800,000 first university degrees in S&E fields. Students in North America earned more than 600,000 S&E bachelor's degrees. Students in Asia and Europe generally earn more first university degrees in natural science and engineering (NS&E) than in social sciences, whereas the converse is true for students in North America. (See figure 2-25.)

Trend data for bachelor's degrees show that the number earned in the United States remained stable or declined in the 1990s in all fields except psychology and biology. The number of engineering degrees earned in the United States declined from 1986 to 1991, remained nearly stable at the 1991 level for several years, and declined again in 1998. The number of computer science degrees declined from 1986 to 1990, remained essentially flat throughout the 1990s, and increased in 1998. In contrast, trend data available for selected Asian countries show strong growth in degree production in all S&E

[8]A first university degree refers to the completion of a terminal undergraduate degree program. These degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree (for example, *laureata* in Italy, *diplome* in Germany, *maitrise* in France, and *bachelor's degree* in the United States and in Asian countries).

Reverse Flow

Systematic data are not available on the contributions that returning Ph.D.-holding scientists and engineers make to the science and technology (S&T) infrastructure of their home countries. Evidence suggests that they fill prominent positions in universities and research institutes. For example, college catalogs of universities in developing countries show the location of the doctoral education of science and engineering (S&E) faculty. Senior academic staff and directors of research centers typically receive their doctoral education from research universities in the United States, the United Kingdom, or France.* The following are four broad categories of reverse flow that contribute to the circulation of S&T knowledge. They are distinguished by location and duration. The first two categories relate to actually moving back home for permanent or temporary positions. The last two categories relate to short- and long-term activities conducted with the home country while employed abroad.

Employment Offers to Scientists and Engineers Trained Abroad

Taiwan and South Korea have been the places most able to immediately absorb Ph.D.-holding scientists and engineers trained abroad who contribute through teaching and research in universities and research parks (NSF/SRS 1998). Research and development (R&D) centers of foreign businesses in these countries also employ returning scientists and engineers, e.g., Motorola Korea Software Research Center and the South Korea International Business Machines (IBM) Tivoli Software Development Center (*The Korean-American Science and Technology News* 1998). Multinational R&D centers are also being established in China by Microsoft, Hewlett-Packard, and IBM (*China Daily* 2001a). A relatively small percentage of South Korean and Taiwanese doctoral recipients from universities in the United States plan to stay in the United States. (See appendix table 2-32.) Many of those who remain in the United States to pursue academic or industrial research experience eventually return to their home country.

In contrast, China and India can offer S&T employment to only a small fraction of their students who earn advanced degrees in S&E fields at universities in the United States. Most of these students remain in the United States, initially for postdoctoral research or for research in industry (NSF/SRS 1998). Those who do return later are usually recruited for a national research priority; for example, the recently established Brain Research Center in New Delhi hired top Indian scientists from home and abroad (American Association for the Advancement of Science 1999). The human genome center at the Chinese Academy of Science's Institute of Genetics in China attracted top young Chinese microbiologists and geneticists for 20 research groups formed in Beijing and Shanghai to sequence part of the human genome (Li 2000). More programs are being created in China to attract outstanding scientists and engineers to top faculty positions and to lead research programs in their disciplines (Guo 2001).

Besides immediate or delayed returns, reverse flow to a home country sometimes occurs after a long, distinguished scientific career abroad. Incidents of prominent scientists returning to their countries are noted in science journals. For example, Yuan T. Lee earned a doctorate in chemistry at the University of California–Berkeley, headed a top laboratory, and eventually earned a Nobel Prize for his research. Many years later, he returned home to head Taiwan's Academia Sinica, a collection of 21 research institutes (Nash 1994).

Temporary Positions for Scientists and Engineers Trained or Working Abroad

Besides various permanent positions, reverse flow can be the result of an offer for an attractive temporary S&E position or for access to high-technology parks with desirable conditions. For example, the government of Ireland's Science and Technology Agency (FORFAS) is funding basic science with five-year grants that are attempting to draw Irish scientists and engineers back to establish laboratories in Irish universities. (Previously educated in Ireland, the graduates left for employment in the United Kingdom or the United States.) Although not offered permanent positions, they would have funding to lead a research area for five years.† A different type of temporary arrangement is China and Taiwan's use of preferential status (no taxes for two to three years) for those who will try to start up a company within an industrial park (*China Daily* 2001b). Another example of a temporary position is transferring to an R&D position within a multinational firm operating in the home country or accepting a two- to three-year appointment in the home country while maintaining ties in the United States. For example, in 2001, Hong Kong University of Science and Technology hired Dr. Paul Chu of the University of

*See, for example, the international academic credentials of the S&E faculty in recent college catalog of Bilkent University, Ankara, Turkey, and Hong Kong University of Science and Technology.

†Personal communication with Rhona Dempsey, Manager, S&E Indicators, Science & Technology Division, The National Policy and Advisory Board for Enterprise, Trade, Science, Technology and Innovation (FORFAS), NSF, Arlington, VA, March 2001.

Houston as its new president for a three-year appointment, but he maintains his laboratory on High Temperature Superconductivity in Houston (Cinelli 2000).

Long-Term Collaborative Research Arrangements

Some scientists remain abroad but establish and maintain a long-term relationship with researchers in their home country through periodic visits, international conferences and workshops, short courses and workshops at their home institutions, and collaborative research. For example, Samuel Ting, Nobel laureate in physics, Professor at the Massachusetts Institute of Technology (MIT), and member of Taiwan's Academia Sinica, encourages collaboration of teams of scientists in 16 countries and Taiwan. As chairman of the Alpha Magnetic Spectrometer (AMS) research program under the Department of Energy and National Aeronautics and Space Administration, Ting established international collaboration with Taiwanese researchers to manufacture all AMS electronics (*Taipei Update* 2001). In addition, U.S. cooperative science programs with China and India funded by the National Science Foundation often provide grants to Chinese and Indian scientists in the United States collaborating with a home-country scientist.[†]

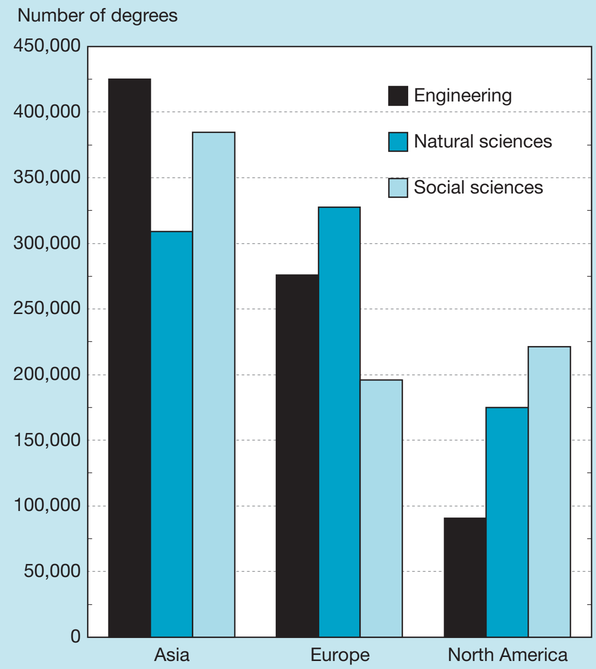
Intermittent Networking

Another mechanism for scientific information flow is networking of scientists abroad with scientists in their home country. Because of economic and political crises, several Latin American countries have lost scientists and engineers to other countries in the region or outside Latin America. Colombia was the first to attempt to link to these "lost" scientists and engineers working abroad and to reframe the concept from "brain drain" to "brain gain." In the early 1990s, the Caldas program in Colombia linked all expatriate Colombian scientists to advise on scientific and economic development schemes (Charum and Meyer 1998). Approximately 40 countries have since devised such networking schemes, and others are working to implement programs (Meyer 2001).

Some countries are able to use all types of reverse flow, absorbing their scientists and engineers in temporary or permanent positions and promoting links through international collaboration or visits.

[†]See abstracts of awards for grants and workshops with China and India at the NSF website: <http://www.nsf.gov>.

Figure 2-25.
First university degrees in S&E fields in selected countries, by region: 1999 or most recent year



NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences, as well as mathematics and computer sciences. Social sciences include sociology, psychology, and other social sciences.

See appendix table 2-18 for countries and economies included within each region.

Science & Engineering Indicators – 2002

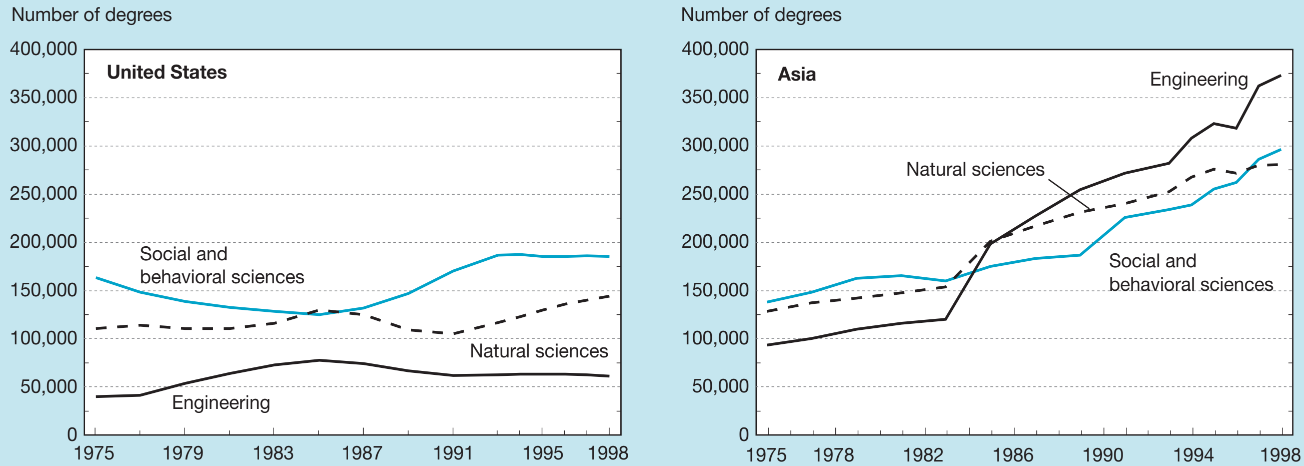
fields. At the bachelor's level, institutions of higher education in Asian countries produce approximately six times as many engineering degrees as do institutions in the United States. (See figure 2-26.) The number of degrees earned in NS&E fields in a country is reflected in the skill level of the labor force and may explain some of Asia's increased capacity in high-technology manufactures and exports. See chapter 6, "Industry, Technology, and the Global Marketplace."

For the past three decades in the United States, overall S&E degrees awarded represented about one-third of the total number of bachelor's degrees. Among some Asian countries and economies, S&E degrees represent a considerably higher proportion of total degrees. In 1999, S&E degrees represented 73 percent of total bachelor's degrees earned in China, 45 percent of total bachelor's degrees earned in South Korea, and 40 percent of total bachelor's degrees earned in Taiwan.

International Comparison of Participation Rates in University Degrees and S&E Degrees

Most countries agree with the notion that a shift to a technology-based economy brings national advantage and that the ability to do so depends on highly educated citizens. Especially important are people educated in science, mathematics, and engineering (Greenspan 2000). A high ratio of the college-age population earning university degrees correlates with better public understanding of science, and a high proportion of the college-age population earning NS&E degrees correlates with the technical skill level of those entering the workforce.

Figure 2-26.
Bachelor's S&E degrees in the United States and selected Asian countries and economies, by field: 1975–98



NOTES: Asian countries and economies include China, India, Japan, South Korea, and Taiwan. Natural sciences include physics, chemistry, astronomy, biological, and earth, atmospheric, ocean, agricultural sciences, as well as mathematics and computer sciences. Data for China are included after 1983.

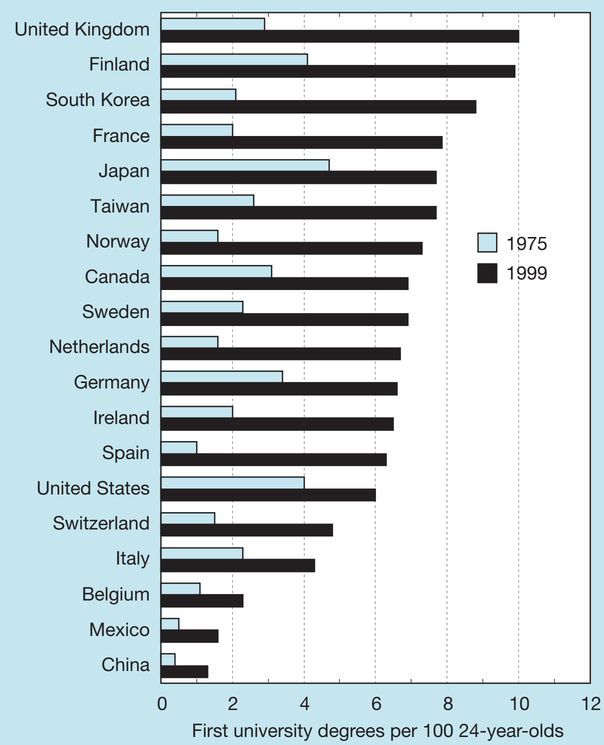
See appendix table 2-33. *Science & Engineering Indicators – 2002*

Traditionally, the United States has been a world leader in providing broad access to higher education. The ratio of bachelor's degrees earned in the United States to the college-age cohort is relatively high—35 per 100 in 1998. However, other countries have expanded their higher education systems, and the United States is now 1 of 10 countries providing a college education to approximately one-third or more of their college-age population. In more than 16 countries, the ratio of natural science and engineering (NS&E) first university degrees to the college-age population is higher than that in the United States. The ratio of these degrees to the population of 24-year-olds in the United States has been between 4 and 5 per 100 for two decades and reached 6 per 100 in 1998. South Korea and Taiwan dramatically increased ratios of NS&E first university degrees earned by 24-year-olds, from 2 per 100 in 1975 to 9 per 100 in South Korea and almost 8 per 100 in Taiwan in 1999. At the same time, several European countries have doubled and tripled the ratio of young people earning NS&E first university degrees to between 8 and 10 per 100. (See figure 2-27.)

International Comparison of Participation Rates by Sex

Among Western countries for which degree data are available by sex, the United Kingdom, Canada, and the United States show relatively high participation rates for both men and women in first university degrees. Among these countries, women in the United Kingdom have the highest participation rate in first university degrees. In 1999, the ratio of women-earned first university degrees to the female 24-year-old population was 41 per 100, slightly higher than the ratio in the United States and Canada (38–40 per 100). Women in the United Kingdom and Canada also show high participa-

Figure 2-27.
Ratio of natural science or engineering first university degrees to 24-year-old population, by country or economy



NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, agricultural, as well as mathematics and computer sciences. The ratio is the number of natural science and engineering degrees to the 24-year-old population. China's data are for 1985 and 1999. Other countries' data are for 1975 and 1998 or 1999.

See appendix table 2-18. *Science & Engineering Indicators – 2002*

tion rates of NS&E bachelor's degrees earned. In 1999, the ratio of NS&E first university degrees earned by women in the United Kingdom to the female 24-year-old population was 7.5 per 100, still far less than the rate for U.K. men. Participation rates for men and women in Canada are more similar. (See text table 2-13 and appendix table 2-34.)

In Asian countries, women earn first university degrees at a rate similar to or higher than those in many European countries. However, only in South Korea do women have high participation rates in first university NS&E degrees. In 1998, the ratio of women-earned degrees in these fields to the female 24-year-old population was 4.9 per 100, higher than the participation rate of women in other Asian countries, Germany, or the United States. (See text table 2-13.) Among all reporting countries, women earned the highest proportion of their S&E degrees in natural and social sciences. (See appendix table 2-34.)

International Comparison of Foreign Student Enrollment in S&E Programs

Despite a decline in foreign graduate student enrollment in the United States from 1994 through 1996, the current flow of foreign S&E students to the United States and other industrialized countries is increasing. Some of the factors that have fostered this flow to advanced countries are an increasing focus on academic research and declining college-age populations. See "Demographics and Higher Education." The policies of the European Union (EU) to foster comparable degrees and transferable credits augment the inter-European mobility of students and faculty (Koenig 2001b). The group of traditional host countries for many foreign students (United States, France, and United Kingdom) is expanding to include Japan, Germany, Canada, and Australia. This section compares foreign student enrollment in S&E programs in some of these countries.

The United Kingdom has traditionally educated numerous foreign students, many of whom have come from Britain's former colonies in Asia and North America (particularly India, Malaysia, and Canada). In the 1990s, the proportion of foreign students studying S&E fields in the United Kingdom increased at both the graduate and undergraduate levels. From 1995 to 1999, foreign undergraduate students in S&E increased from 8.8 to 11.6 percent. Engineering received a higher concentration of foreign students as undergraduate enrollment in engineering in U.K. universities declined from 113,000 in 1995 to 100,000 in 1999. At the same time, the enrollment of foreign students in engineering rose from 16,000 in 1995 to 21,000 in 1999, representing 21 percent of all undergraduate engineering students in U.K. universities in 1999, up from 14 percent in 1995. (See text table 2-14 and appendix table 2-35.)

During the same period, U.K. universities also increased enrollment of foreign students within their graduate S&E departments. Foreign S&E graduate student enrollment rose from 28,848 in 1995 to 36,631 in 1999, an increase of 27 percent. Concurrently, U.K. universities increased the percentage of foreign S&E students at the graduate level from 28.9 to 31.5 percent. Percentages of foreign students differ by field. In 1999, foreign student graduate enrollment reached 37.6 percent in engineering and 40 percent in social and behavioral sciences. (See figure 2-28 and appendix table 2-35.)

European countries are receiving more students from within EU countries. By 1999, at U.K. universities, the number of foreign graduate students from other EU countries was three times higher than the number of foreign students from Britain's former colonies (Malaysia, Hong Kong, and India). (See text table 2-15 and appendix table 2-35.) Graduate students from EU countries represent approximately 7 percent of the graduate students in sciences in U.K. universities and approximately 11 percent of the graduate engineering students. Chinese students, who represent about one-third of foreign S&E graduate students at universities in the United States, make up only 4 percent of S&E graduate students at U.K. universities. (See appendix tables 2-21 and 2-35.) Students from Greece have traditionally attended other European universities and universities in the United States for graduate education. After Greece, however, German students account for the second highest number of foreign graduate students at U.K. universities.

Text table 2-13.
Ratio of NS&E degrees to 24-year-old population, by country and sex: 1998–99

Country	Female	Male
Japan	2.3	12.8
United Kingdom	7.5	12.5
South Korea	4.9	12.4
Canada	5.7	7.9
Germany	4.3	7.7
United States	4.6	7.5
Mexico	0.9	2.4

NS&E = natural science and engineering

NOTES: Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, agricultural, as well as mathematics and computer sciences. The ratio is the number of NS&E degrees to the 24-year-old population.

See appendix table 2-34.

Science & Engineering Indicators – 2002

Text table 2-14.
Enrollment of foreign students in undergraduate engineering, selected countries: 1998–99

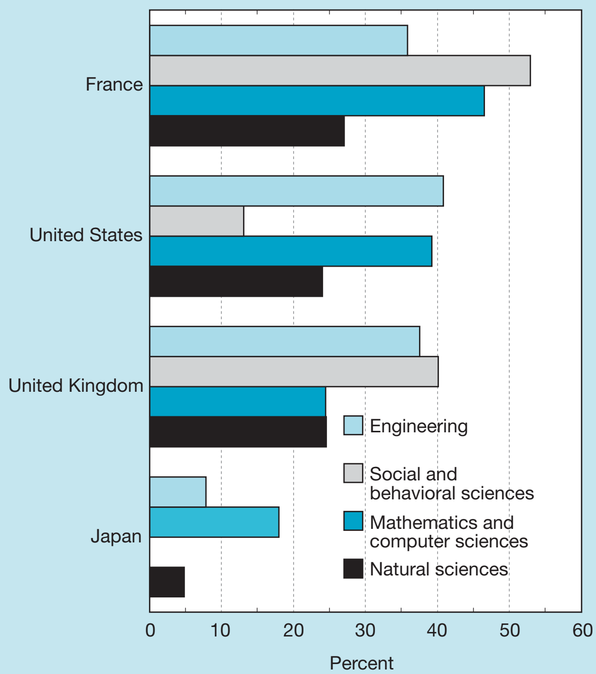
Country	Total engineering enrollment	Foreign enrollment	Percent foreign
United Kingdom	99,900	20,811	20.8
United States	366,991	21,110	5.8
Japan	471,310	3,322	0.7

NOTE: U.S. data are 1998; U.K. and Japan data are 1999.

SOURCES: American Association of Engineering Societies, Engineering Workforce Commission, *Engineering and Technology Enrollment, Fall 1999* (Washington DC, 2000) and appendix tables 2–35 and 2–37.

Science & Engineering Indicators – 2002

Figure 2-28.
Foreign graduate student enrollment in selected countries, by field: 1999



NOTES: French data include foreign doctoral students only; Japanese data include mathematics in natural sciences and computer sciences in engineering. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix tables 2-20, 2-35, 2-36, 2-37, and 2-38.

Science & Engineering Indicators – 2002

Text table 2-15.
Foreign graduate students in S&E fields in U.K. universities, by region of origin: 1999

Region	Number
Total	36,000
Europe	15,000
Asia	10,000
Africa	3,000
Middle East	3,000
North America	3,000
South America	1,000
Central America	600

SOURCE: Higher Education Statistics Agency, unpublished tabulations (2001).

Science & Engineering Indicators – 2002

Foreign students also are attracted to France for graduate programs in S&E. French universities have a long tradition of educating foreign students and have a broad base of countries of origin of foreign doctoral students (more than 150), primarily developing countries in Africa, Latin America, and Asia. Approximately 15 percent of the foreign students in French doctoral programs come from neighboring European countries. In 1998, most of the 17,000 foreign doctoral students who entered French universities enrolled in S&E fields. (See appendix table 2-36.) Foreign students enrolled in S&E doctoral programs represent about 26 percent of S&E doctoral enrollment, somewhat smaller than the proportion of foreign students in U.S. graduate enrollment. (See figure 2-28.)

Japan and Germany also are attempting to bolster their enrollment of foreign students in S&E. Japan's goal of 100,000 foreign students, promulgated in the 1980s, has never been met but is once again being discussed as a serious target. In 1999, 55,000 foreign students enrolled in Japanese universities, mainly at the undergraduate level (34,000) and concentrated in social sciences (13,000) and engineering (3,000). In that year, about 22,000 foreign students enrolled in graduate programs in Japan, mainly from China and South Korea, representing 10 percent of the graduate students in S&E fields. (See appendix table 2-37.) Germany is also recruiting foreign students from India and China to fill its research universities, particularly in engineering and computer sciences (Grote 2000; Koenig 2001a).

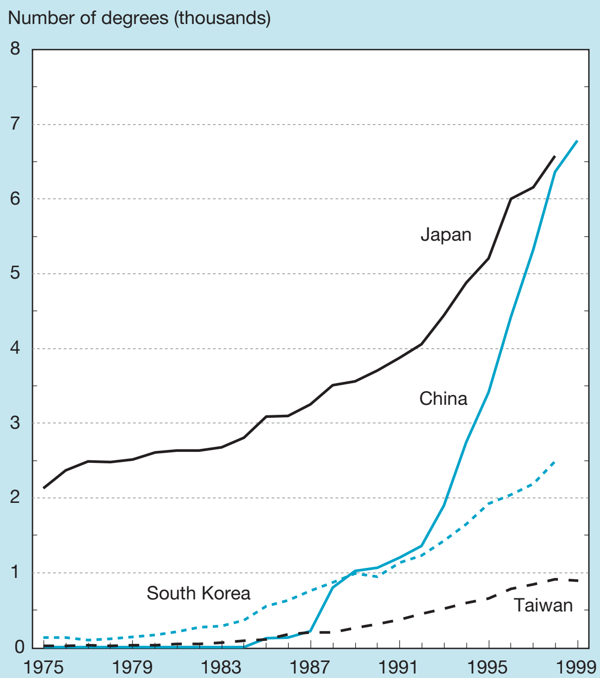
International Comparison of Doctoral Degrees in S&E Fields

The development of increasing institutional capacity to provide advanced S&E education through the highest levels is indicated in trend data for earned doctorates in selected countries of Europe and Asia. Japan has doubled its S&E doctoral degree production within the past decade. Developing Asian countries, starting from a very low base in the 1970s and 1980s, have increased their S&E doctoral education by several orders of magnitude. China, Japan, South Korea, and Taiwan have established new institutions for graduate education in S&E and expanded their S&E graduate programs in existing national universities. China now has the largest capacity for S&E doctoral degree production in the Asian region (see figure 2-29) and ranks fifth in the world. In Europe, France, Germany, and the United Kingdom have almost doubled their S&E doctoral degree production in the past two decades, with slight declines in 1998. (See figure 2-30.) All of these countries are engaged in reforms to improve the quality of doctoral research programs. See sidebar, "International Efforts in Doctoral Reform."

The growing capacity of some developing Asian countries and economies (China, South Korea, and Taiwan) for advanced S&E education decreases the proportion of doctoral degrees earned by their citizens in the United States. (See figure 2-31.) For example, in the past five years, Chinese and South Korean students earned more S&E doctoral degrees in their respective countries than in the United States. Taiwanese students have also become less dependent on the United States for advanced training; in 1999, for the first time, they earned more S&E doctoral degrees at Taiwanese universities than at universities in the United States.

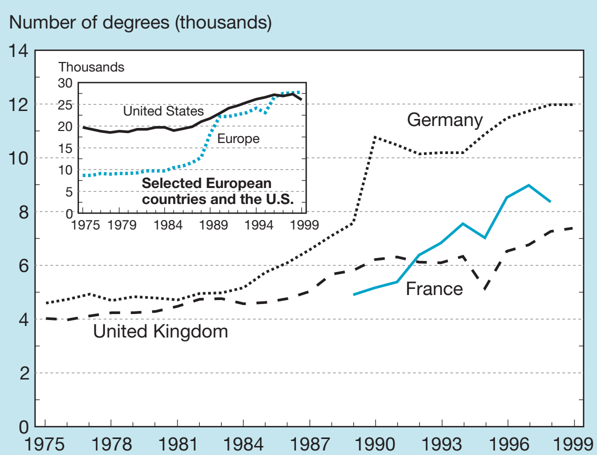
In 1999, Europe produced far more S&E doctoral degrees (54,000) than the United States (26,000) or Asia (21,000). Considering broad fields of science, most of the doctorates earned in natural sciences, social sciences, and engineering are earned at European universities. The United States awards

Figure 2-29.
Doctoral S&E degrees earned in selected Asian countries and economies: 1975–99



See appendix table 2-39. *Science & Engineering Indicators – 2002*

Figure 2-30.
Doctoral S&E degrees in selected industrialized countries: 1975–99



NOTES: The peak in the data from Germany in 1990 reflects the inclusion of degrees from former East Germany. The inset combines the three European countries.

See appendix table 2-40. *Science & Engineering Indicators – 2002*

more doctoral degrees in natural and social sciences than Asian countries. (See figure 2-32.)

Trend data for NS&E doctoral degrees (excluding social sciences) show that Asian universities educated more students at the doctoral level in these fields than universities in the United States in the late 1990s. (See figure 2-33.) In 1999, Asian universities awarded more engineering doctoral degrees but fewer natural science degrees than universities in the United States. (See appendix tables 2-39 and 2-40.)

Considering the proportion of S&E doctoral degrees by sex, women in Europe and the United States earn a higher proportion of such degrees than women in Asia. Women in France and the United States earned more than a third of S&E doctoral degrees in their respective countries in 1999. Women in Japan, Taiwan, and South Korea earned about 10 percent of such degrees. (See appendix table 2-43.)

International Comparison of Foreign Doctoral Recipients

Like the United States, the United Kingdom and France have a large percentage of foreign students in their S&E doctoral programs. In 1999, Germany was the top country of origin of foreign S&E doctoral degree recipients in the United Kingdom, China was the top country earning S&E doctoral degrees in the United States, and Algeria was the top country of origin of foreign students studying for S&E doctoral degrees in France. (See appendix tables 2-32, 2-36, and 2-44.) In 1999, foreign students earned 44 percent of the doctoral engineering degrees awarded by U.K. universities, 30 percent of those awarded by French universities, and 49 percent of those awarded by universities in the United States. In that same year, foreign students earned more than 31 percent of the doctoral degrees awarded in mathematics/computer sciences in France, 38 percent of those awarded in the United Kingdom, and 47 percent of those awarded in the United States. (See figure 2-34.) In addition, Japan and Germany have a modest but growing percentage of foreign students among their S&E doctoral degree recipients. (See appendix table 2-45.)

International Comparison of Stay Rates

Data similar to the data on “plans to stay” in the annual SED are available on the first destination of foreign doctoral students in the United Kingdom and France after earning their degree. Data from the U.K. Higher Education Statistics Agency show that, in 1998, most foreign S&E doctoral degree recipients at U.K. universities returned home after earning their degree. In fact, among the 10 top countries of origin, all doctoral recipients from Malaysia and Turkey returned to their home country. Ireland is the only exception, with 45 percent of doctoral recipients returning to Ireland as their first destination after receiving their degree. (See text table 2-12.)

Doctoral survey data from the French Ministry of Education, Research, and Technology show that the return rate for foreign S&E doctoral recipients is lower in France than in the United Kingdom. Data are not available on the return rates of French foreign doctoral recipients by countries of origin, but return rates are available by S&E field of study. In 1998, the overall return rate of foreign doctoral recipients from France to their countries of origin was 28 percent in natural sciences and 20 percent in engineering fields. (See text table 2-16.)

International Efforts in Doctoral Reform

Doctoral reforms in European and Asian countries are strengthening the university sector to become an explicit component of national innovation systems. The goals are to develop the capacity for breakthrough research leading to innovative products and successful markets, to stem "brain drain," and to attract top scientists to the country (NSF/INT 2000). Doctoral reforms also include providing national universities with more autonomy in hiring faculty and governance of academic programs and providing additional funds. International networks of universities share curriculum development and distance education.

Asian countries are using various mechanisms to improve the quality of doctoral programs and to upgrade equipment and facilities for academic research. World-class facilities often require international partnerships (Bagla 2000). For example, the Indian Institute of Technology (IIT) in Delhi is partnering with the International Business Machine research center on its campus for graduate research opportunities and exchange of faculty. In China, Shanghai's Fudan University and Bell Labs have a joint laboratory for software development and information technology (IT) (*China Daily* 2001b). In addition, research parks throughout Asia are concentrating high-technology industries next to top universities to attempt to create a "Silicon Valley." For example, Beijing's research park includes Peking University, the Chinese Academy of Sciences, and 4,000 high-technology enterprises (*China Daily* 2001a).

European countries are experimenting with doctoral reforms that prepare students not only to increase the store of basic science but also to apply knowledge to innovative technologies and find solutions to the problems confronted by society (Carlson 2001). Doctoral reform in France brings university research programs closer with the network of national laboratories (CNRS). For example, the CNRS Laboratory of Material Physics and two university labs are forming a Materials Center to be part of a large research complex outside Rouen (Carlson 1999).

Doctoral reforms in Europe also include international partnerships to create centers of excellence, some through the EU and some trans-Atlantic centers. The centers of excellence are designed both to improve the quality of research and to stem brain drain to other countries. For example, the University of Cambridge in Cambridge, England, and the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, are collaborating on the Cambridge-MIT Technology Institute. These two leading research universities will develop common courses and exchange faculty and students (Tugend 1999). A second MIT partnership, the MIT MediaLabEurope in Dublin, will build on Ireland's strength in computer sciences to become a center of excellence in IT for Europe (Birchard 2001).

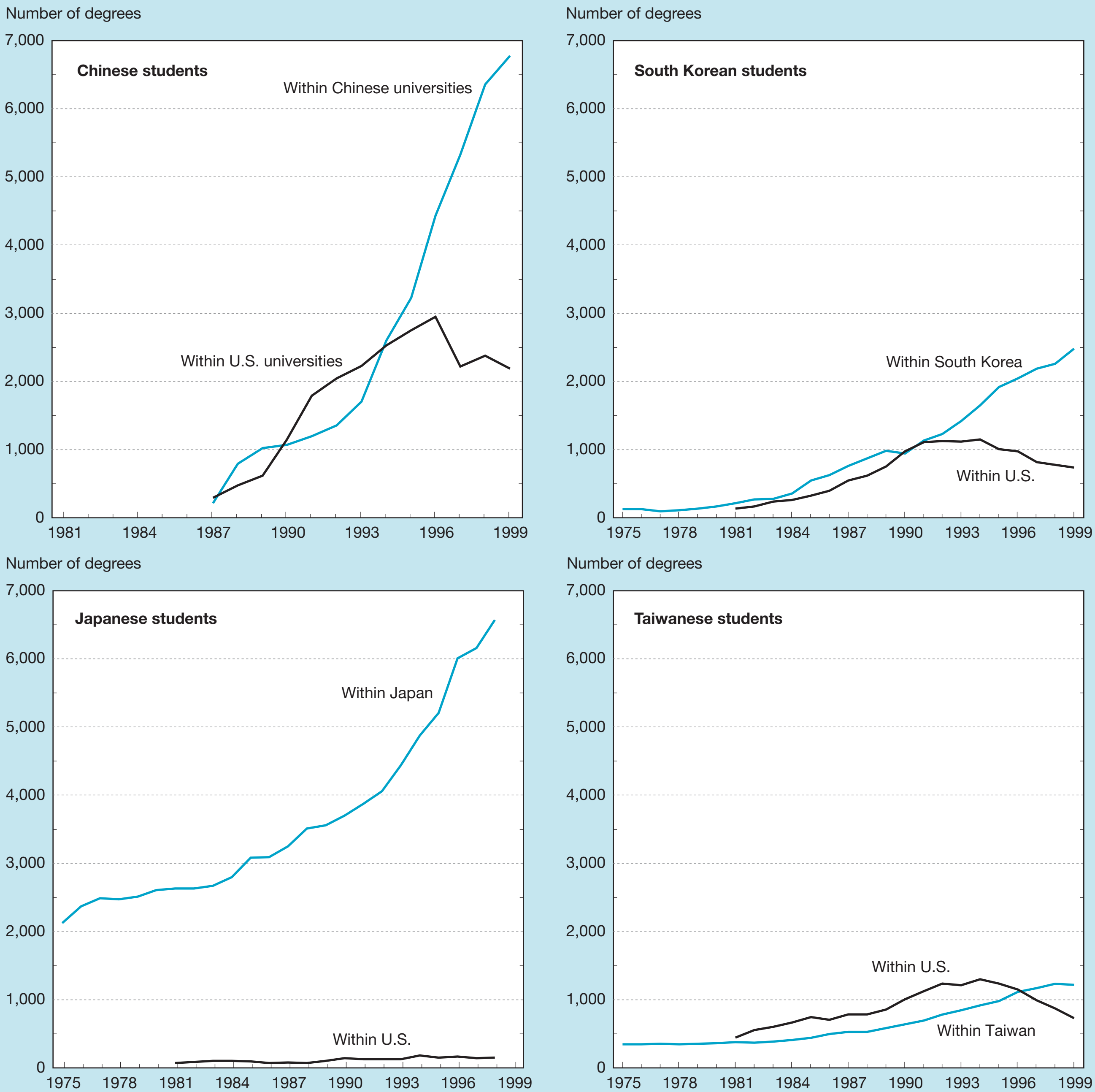
Countries and other places are using various funding sources, either public or private, to upgrade equipment and facilities. For example, Taiwan is publicly funding infrastructure improvements, as are industrialized countries such as Japan and those within the European Union. The U.K. government has recently committed large funds to improve deteriorating facilities and to raise stipends for doctoral students (Stone 2000; Urquhart 2000). China has used international funding sources to improve higher education (Hayhoe 1989) and is assisting the top universities in becoming financially independent through their partnerships with high-technology industries (China Daily 2001b). Hong Kong and South Korea have built science and technology (S&T) universities with business donations. The philanthropy of Indian scientists and engineers in the United States with successful companies is upgrading the IIT's facilities and creating new S&T universities in India (Goel 2000; Bagla 2000).

Conclusion

Students in the United States are as interested in studying some fields of science as they were in the past, but the declining level of interest in engineering and physical sciences still raises national concern. From 1975 to 1998, approximately one-third of all bachelor's degrees were earned in S&E fields. However, the distribution among natural sciences, social sciences, and engineering has changed. The approximately 12 percent of degrees earned in natural sciences are not as evenly distributed across physical and biological sciences as in previous decades. The number of degrees earned in biological sciences continues to increase, whereas the number earned in other natural sciences is dropping off. Engineering degrees, which represented 8 percent of all bachelor's degrees awarded in 1986, slowly dropped to 5 percent of all bachelor's degrees awarded in 1998. In addition, other countries award a higher percentage of bachelor's degrees in S&E fields; among European and Asian countries, the average is about 40 percent and it is considerably higher for some emerging Asian countries.

The United States has programs to increase access to S&E education for groups that were formerly underrepresented in S&E fields. Because these groups represent the growing segment of the population in the United States, an adequate future workforce will require that minorities choose careers in S&E. To date, modest progress has been made toward increasing the proportion of these minority college-age populations earning NS&E degrees. In 1998, among whites, the ratio of

Figure 2-31.
Doctoral S&E degrees earned by Asian students at home universities and U.S. universities: 1981–99



NOTES: Chinese degree data not available for earlier years. U.S. data include foreign doctoral recipients on either permanent or temporary visas.

See appendix tables 2-39 and 2-41.

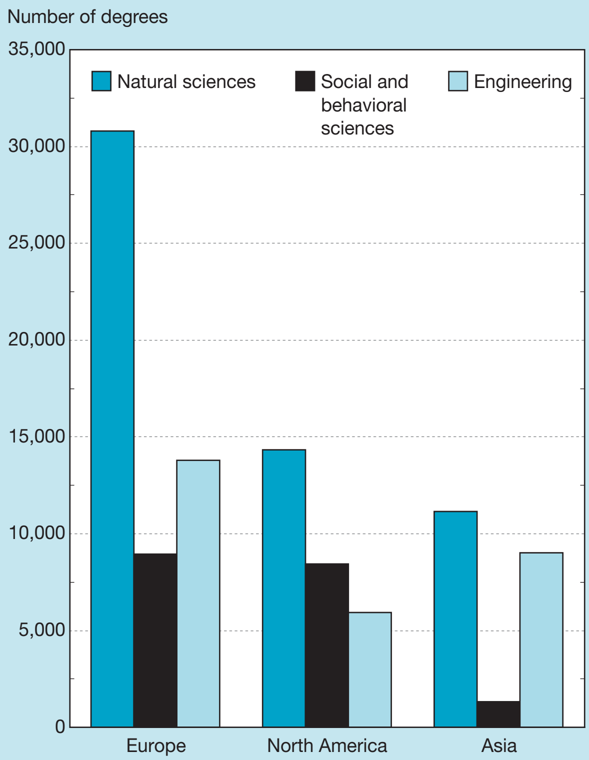
Science & Engineering Indicators – 2002

NS&E degrees to the college-age population was 6 per 100. Among underrepresented minorities, the ratio was less than half that of whites.

Further research is needed to quantify the increasing access to S&E education outside traditional higher education institutions. That is, what is the effect of nondegree programs in engineering and IT completed in the workplace through distance education and certificates?

This chapter discussed indicators of expanding access to S&E education in several world regions and modest expansion of access to minority groups within the United States. Many countries have significantly increased the proportion of their college-age population earning first university degrees in NS&E fields. In addition, they have expanded their institutional capacity for S&E graduate programs and doctoral education. This expansion indicates a share-shift in the proportion of S&E doc-

Figure 2-32.
Doctoral S&E degrees in Europe, North America, and Asia: 1999

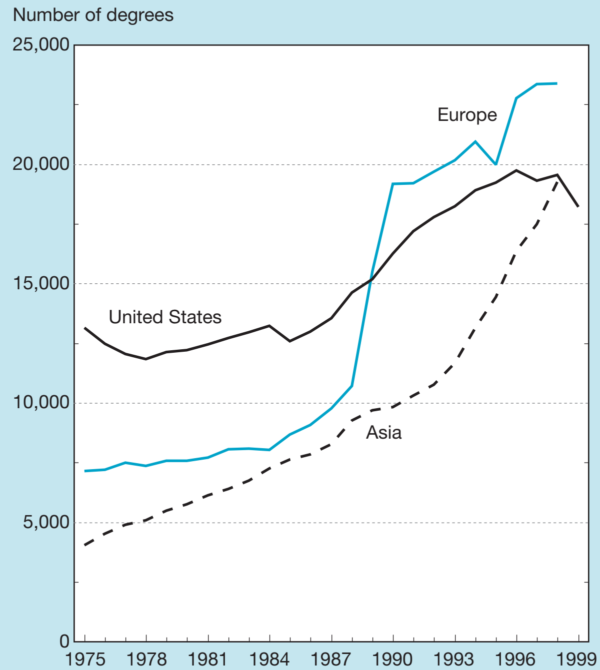


NOTE: Natural sciences include physics, chemistry, astronomy, and biological, agricultural, earth, atmospheric and ocean sciences, as well as mathematics and computer sciences.

See appendix table 2-42 for countries and economies included in Europe, North America, and Asia.

Science & Engineering Indicators – 2002

Figure 2-33.
Doctoral NS&E degrees in the United States, Europe, and Asia: 1975–99



NOTES: Natural sciences include physics, chemistry, astronomy, and biological, agricultural, earth, atmospheric and ocean sciences, as well as mathematics and computer sciences. Europe includes France, Germany, and the United Kingdom. Asia includes China, India, Japan, South Korea, and Taiwan.

See appendix tables 2-39, 2-40, and 2-24.

Science & Engineering Indicators – 2002

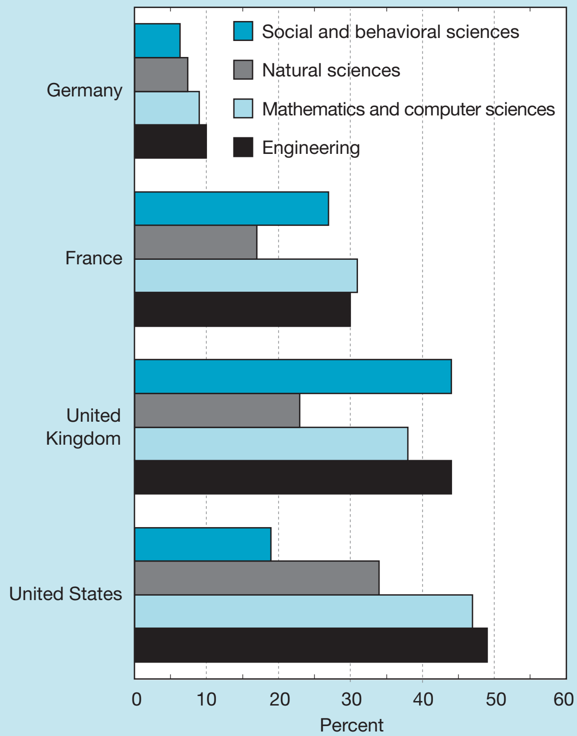
toral degrees earned outside the industrialized countries. The challenge to the scientific leadership of the United States and to corporate R&D[9] from this share-shift is to devise effective forms of collaboration and information exchange to benefit from, and link to, the expanding proportion of science performed abroad. Measures of collaboration in international coauthorship of scientific articles may be an important indicator for monitoring the globalization of science. For example, the degree to which international coauthorship increases or decreases could indicate how the United States is staying in touch with expanded research abroad.

Several advanced industrial countries are also expanding recruitment of foreign S&E graduate students to maintain and strengthen their academic R&D efforts, considered to be of increasing importance to innovation (Porter and Stern 1999). Little evidence suggests that other countries are competing with graduate schools in the United States in the recruitment of foreign S&E students. The number of foreign graduate students is increasing in universities in the United States and in several other countries. Small shifts in graduate students in Asia entering Japanese or Australian universities may occur because of proximity and active recruitment by those countries. There are also small downward shifts in the number of foreign graduate students to universities in the United States from some traditional feeder countries and economies that have expanded their graduate programs, such as South Korea and Taiwan.

Because mobility of people is the main mechanism for technology transfer, the flow of foreign students abroad and reverse flow of students back to their home countries provide an opportunity for S&T development. Whether S&E education abroad eventually contributes to the home country depends on its S&T policy and commitment to employing highly skilled professionals. China and many other developing countries have shown that they need not be able to offer employment to their scientists and engineers educated abroad to receive their scientific advice on development schemes or research directions (Meyer 2001). Research is needed on the appropriate mix of foreign S&E doctoral recipients who "stay abroad" and "return home" for mutual benefit to the host and sending countries. The beneficial mix of immediate and delayed returns and the variety of cooperative activities associated with reverse flow are likely to differ for individual countries, regions, and stages of development.

[9]See, for example, John E. Pepper, Chairman of the Board, The Procter & Gamble Company, "National Benefits from Global R&D," Industrial Research Institute Annual Meeting. Williamsburg, VA, May 26, 1999.

Figure 2-34.
Doctoral S&E degrees earned by foreign students in selected countries, by field: 1999



NOTES: U.S. data include those on permanent and temporary visas. Natural sciences include physics, chemistry, astronomy, and earth, atmospheric, ocean, biological, and agricultural sciences.

See appendix table 2-45. *Science & Engineering Indicators – 2002*

Text table 2-16.
Foreign S&E doctoral recipients in France who returned home, by field: 1998

Field	Total recipients	Percentage who returned
Natural sciences	672	28
Mathematics and computer sciences	262	17
Agriculture	37	5
Social sciences	262	44
Engineering	551	20

NOTE: Natural sciences include physics, chemistry, astronomy, and biological, agricultural, earth, atmospheric, and ocean sciences.

SOURCE: Government of France, Ministère de l'Éducation Nationale, de la Recherche, et de la Technologie, *Rapport sur les Études Doctorales* (Paris, 2000).

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